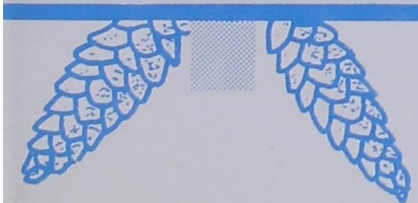
Annual Report

1961

LAKE STATES FOREST EXPERIMENT STATION

FOREST SERVICE • U.S. DEPARTMENT OF AGRICULTURE



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TOOLING FOR PROGRESS

M. B. Dickerman
Director

THE PAST few years have seen significant developments in forest research. Several trends have been noticeable: national recognition of the key place research has in accelerating economic growth; day-to-day evidence that population growth is creating problems concerning the use and productivity of forest land; and an accelerated shift toward a greater effort in basic research so that a sound program of applied research can be built for the future. These trends have had a decided impact on this Station's activities.

Program requirements have necessitated greater specialization by staff members. In recruiting new staff, this point has been given prominence. Thus the scope of staff specialization now includes soil scientists, plant physiologists, engineers, social scientists, ecologists, and geneticists, as well as research foresters, forest economists, entomologists, pathologists, and forest products technicians. Other research positions will further broaden the fields of specialization.

Along with staff specialization has been the recognition that greater emphasis must be placed on more adequate research facilities. Since 1959, two new laboratories have been completed, one for genetics research, the other for northern conifer research. This past year, construction began on a small laboratory at Marquette, Mich., where northern hardwoods research will be centered. In 1961 Congress appropriated funds for a central Station laboratory and administrative headquarters building at St. Paul. To be located on the St. Paul Campus of the University of Minnesota and adjacent to the School of Forestry, this facility is now in the planning stage. A small laboratory is also being planned for Bottineau, N. Dak., where the Station's research concerning shelterbelts in the Northern Plains will be centered.

Previous reports have noted specific developments in new programs. Recognizing that not all problems in forestry can be resolved by biological and social studies, the Station moved in 1961 to initiate a program in Forest Engineering Research. This is being located at Houghton, Mich., in cooperation with the Michigan College of Mining and Technology. The objective in this new research undertaking will be to prescribe improved equipment for establishing, maintaining, and harvesting northern hardwoods and conifers. The senior project leader for this undertaking is Rulon B. Gardner, an engineer who transferred from Juneau, Alaska.

With all these things going on, the Station published about 70 scientific papers during the year. These are listed in the back of this report.

Following a brief review of Division activities on the next few pages, the balance of this report concentrates on summarizing recent forest improvement research. The results of the forest survey project have shown marked changes from the depleted forests of the thirties to the second-growth forests of the sixties. If these new forests are to be fully productive, not only of timber but also of water, wildlife, and other forest products, much greater effort must be placed on forest improvement in the years immediately ahead. Thus in this report we summarize some of the main research contributions in the field of forest improvement and some of the opportunities for research in the future.

M. B. Dickerman, Director

HIGHLIGHTS OF STATION ACTIVITIES

Robert D. McCulley
Chief, Forest Management

THE BASIC silvicultural work of the Division of Forest Management Research was maintained at about the same strength as during the previous year. Resources were increased in several specializations, among them fire, wildlife habitat, wildlife damage, and genetics.

Among additions to forest management personnel were Dr. Forest Stearns, who will direct research in forest and wildlife habitat relationships, and Dr. Knud Erik Clausen, who will do tree improvement research on northern hardwood species. Zigmond A. Zasada, a member of the Station since 1946 and an expert in aspen management research, transferred to the Washington Office.

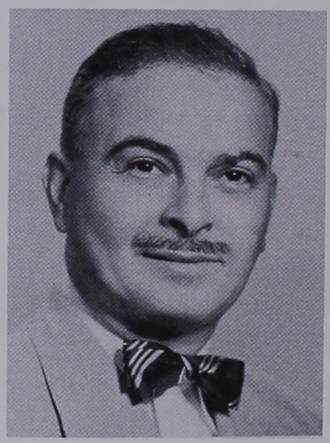
Exchange of information and ideas among forest scientists is essential to provide for proper coordination of widely dispersed effort. In the past year we were hosts to a national meeting of specialists in seeding and planting. A resurgence of interest in direct seeding as a substitute for planting is being felt in this region and throughout the nation. Cost is the big bottleneck in restocking idle acreage, and where seeding is effective it is less expensive than planting.

We took part in a meeting of Department of Agriculture agencies concerned with relationships of tree growth to soils in the Plains. The intent was to bring united effort to bear on mutual problems.

A special occasion in 1961 was the Lake States Forest Fire Research Conference at Green Bay, Wis. Several organizations participated in this, and nearly 200 foresters and landowners concerned with the fire problem attended. As a result of this conference, the thinking on fire research needs and programs took specific form. The Station assisted in organizing the conference, participated in presentations, and on recommendation of the conference is now drawing up a specific program of cooperative fire research.

Since management research deals with problems of the land, a natural means of disseminating research information is through technical group discussion on research plots and in experimental forests. The long record of such activities continued during the year with strong emphasis on conifer and hardwood silviculture at Grand Rapids, Minn., and Marquette, Mich. The geneticists at Rhinelander, Wis., and their associates in other organizations were hosts to the professional foresters of the Michigan-Wisconsin Section of the Society of American Foresters, and discussed progress to date in their rapidly expanding field. Research on the various phases of tree improvement were observed in the laboratory, in the nursery, and in a number of field plantings and other plots.

Forest management research relating directly to forest improvement is noted later in the report. However, a recently completed project of significant scope deserves special mention. This is an investigation of spruce bogs by Dr. M. L. Heinselman. The primary objective was to shed light on some of the bog characteristics that are associated with level of productivity for timber production. Results will be submitted for publication in 1962.



Sidney Weitzman
Chief, Watershed Management

PROGRESS IN the Division of Watershed Management Research was made along several fronts. First, each of our three field units now has an experimental forest dedicated to watershed research. The wide interest in this field of research is indicated by the fact that these experimental areas were made available through the co-

operation of the National Forest Administration, the Wisconsin Conservation Department, the Minnesota Conservation Department, Itasca County, Minn., and private citizens.

During the 1961 field season major effort was concentrated on long-range instrumentation on each experimental forest. Under the direction of Roger Bay, the bog and swamp hydrology project in northern Minnesota has instrumented five swamp watersheds with automatic gaging structures and recording and nonrecording wells. On the Coulee Experimental Forest near La Crosse, Wis., over 25 devices were installed for measuring surface runoff and springflow. For the ground water project in Michigan we have installed over 100 ground water wells ranging in depth from a few feet to over 80 feet.

Work was started on some new and unique aspects of watershed management research:

1. Early results of studies by Don H. Boelter in northern Minnesota indicate the complex nature of organic peats. Like mineral soils, peats are made up of a series of horizons or layers. Each layer, however, exhibits even greater differences in water-holding capacities and watershed properties than do mineral soils. Present studies of the hydrologic properties of organic soils indicate that wide and rapid water table fluctuations in swamps may result from a very small amount of precipitation. These studies will help determine the role of wetlands as natural reservoirs.

2. In conjunction with our ground water research in Michigan, an electrical resistivity meter is being tested on the Udell Experimental Forest. This cooperative study with Michigan State University will explore the possibility of determining the depth and character of underlying soils by taking surface electrical resistance readings.

3. At La Crosse,, Wis., a series of planting studies was undertaken by Dr. J. H. Stoeckeler. One study tests the effect of ground preparation, species, age class, transpiration retardant, shading, aftercare, and site class on survival. Block plantings of various tree species were also established. These plantations will serve as clinical material for future hydrologic soil amelioration and microclimate studies.

4. Basic studies on soil moisture movement and deep recharge to springflow were initiated by Richard S. Sartz and Willie R. Curtis on the Coulee Experimental Forest near La Crosse, Wis.

Advanced training for watershed personnel is receiving strong impetus. Three men are working toward their Ph. D. degrees: Don H. Boelter at the University of Minnesota, W. H. Striffler at the University of Michigan, and Dean H. Urie at Michigan State University.

Ralph L. Anderson
Chief, Forest Disease

THE SERIOUS impact of stain and decay on northern hardwoods and concern about diebacks of unknown cause emphasize the need for a sustained program of research on the disease problems of this forest type. Dr. John H. Ohman was added to the Disease Division staff in 1961 and will work primarily on stain and decay problems of hard maple, yellow birch, and other northern hardwoods. He and Dr. Kenneth J. Kessler, Jr., who is continuing his studies of maple dieback, will be located at the new laboratory at Marquette, Mich. With two scientists now available to devote essentially full time to northern hardwood diseases, substantial progress is being made in this phase of the Station's program.

During the past few years substantial research effort has been concentrated on maple blight, which caused such alarming mortality in northeastern Wisconsin in 1957. Most of the work on this problem by Darroll D. Skilling of this Station and the several cooperators at the University of Wisconsin is completed. Plans are to publish the results in 1962. Mr. Skilling devoted his attention to the influence of environmental factors. Although site and weather factors do have some effects, the general consensus of all studies is that insect defoliation was the key factor causing the damage.

On western white pine, antibiotic treatments have proven to be an effective new tool for controlling blister rust. On eastern white pine small-

scale tests have been inconclusive. This has pointed out the need for greater effort in developing effective methods for use of antibiotics on eastern white pine. The first steps have been taken in developing a large-scale control study in collaboration with the North Central Region of the Forest Service. Ray Weber, who has spent many years in this region in blister rust control, transferred to the Station to work on the project. The Station also will employ a pathologist for this study.

For several years the Station, in cooperation with the University of Wisconsin, has been studying the influence of microclimate on white pine blister rust infection. During the past year, two important Station Papers have been prepared by Dr. E. P. Van Arsdel. The first of these explains how latitude, altitude, topography, and tree cover, through their influence on temperature and humidity and thus on the chances of favorable infection-weather occurring, cause great differences in the risk of serious infection. The second provides recommendations for modifying blister rust control practices to fit local environmental situations. The region is divided into four hazard zones based on general climate, and in each the specific control practices are keyed to local topographic and tree-cover characteristics. The results of this work have already brought about a substantial reduction in control costs by eliminating ribes eradication on some sites in the more southern low-risk zone where the hazard is not great enough to merit the operation.

The first disease research undertaken at this Station was a large-scale field-plot study on hypoxylon canker of aspen in cooperation with several paper companies. The objective was to determine the influence of environmental factors on the damage caused by this disease, which kills more trees than any other disease in the region. Substantial progress has been made by Gerald W. Anderson in resolving the long-standing and difficult problem of analyzing the vast and complex volume of accumulated data. Some trial runs have been made on computers and are now being evaluated. We hope to have this analysis completed next year.

In some years jack pine nursery stock is severely infected by one or more of the four stem rusts that attack this species. Gerald Anderson has established tests on using antibiotics to control this problem. Preliminary results, which cannot be considered conclusive, show high promise that an effective antibiotic treatment can be developed.

H. J. MacAloney
Chief, Forest Insects

THREE PROJECTS continued to have the attention of the forest insect staff. Since 1956 studies of the spruce budworm have been conducted under the leadership of J. L. Bean. The results are now being summarized in a progress report and the future course of this research is being considered.

The second project deals with the study of forest plantation insects. Dr. William E. Miller's work with the European pine shoot moth has reached the stage where he is summarizing the data for publication. In addition, attention was given to the Zimmerman pine moth in Lower Michigan.

In the hardwood insect project under Dr. H. G. Ewan, it is becoming apparent that the stem borers are responsible for a considerable amount of degrade and cull in Lake States aspen stands. Since the main objective of aspen management is to reduce these losses, there is a great need to study the borers and develop economically feasible control methods.

A survey of forest insects in the Northern Great Plains was completed in 1961 by Dr. Louis F. Wilson. Several insects may present serious problems in the establishment and protection of shelterbelts.

A technical bulletin on the Saratoga spittlebug, authored by Dr. Ewan, was published this year. It summarizes some 15 years of research on the life history of the insect and measures for its control.

Although responsibility for insect surveys was transferred to the Regional Office of the Forest Service in Milwaukee, the Station continued during the summer of 1961 to do the detection and appraisal work for spruce budworm. It is anticipated that in 1962 the Station will not be involved in detection and appraisal work and will concentrate full time on the research projects.

Several changes in personnel resulted from program shifts and other causes. Longtime Division Chief, Dr. H. J. MacAloney, retired in November after 36 years of public service. In July Donald C. Schmiege, formerly in charge of forest insect surveys, transferred to the Northern Forest Experiment Station in Juneau, Alaska. Robert Talerico, who has been working on plantation insects, entered the Army in October.

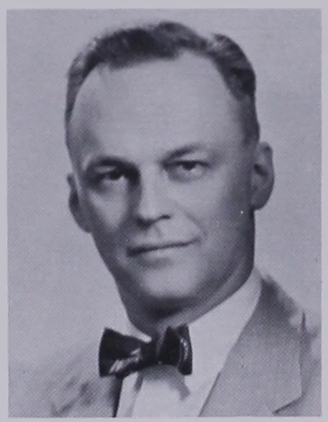
A. W. Toole, Chief
Forest Engineering and
Utilization

PROGRESS WAS made made during the year in several areas of research dealing with regional problems in utilization. Initiation of a program in forest engineering research will help to provide answers to problems of multiple use and the economics of timber production. Studies will be undertaken on low-cost systems and mechanisms for converting deteriorated northern timber stands and deforested areas to full production of timber and other forest uses.

The timber-quality study of sugar maple initiated in 1960 was carried through analysis of the first 45-tree sample and a large portion of the fieldwork for the second 45-tree sample. The purpose here is to determine a tree-value prediction equation by relating external tree stem characteristics to value of the underlying wood for specific products such as lumber. The regression equations for these and succeeding samples will be calculated separately to determine if there are real differences between areas where sugar maple grows. If none is found, the total sample of 180 trees, when completed, will be pooled and analyzed as a unit. This will permit development of a single prediction equation for sugar maple in the Lake States. From this equation accurate quality appraisals can be made of the effects of silvicultural practices, site quality, and possibly even technical wood properties, on the monetary returns from the forest. Substantial aid to this research has been contributed by Woodlands Division, Kimberly-Clark Corporation, Neenah, Wis., during this year.

Timber processing research in utilization of low-grade hardwoods has been carried on through charcoal production in small kilns, use of the short-log bolter saw in processing salvable material from timber improvement cuts, and production of pulp chips from hardwood logging residue. Much of this research was undertaken cooperatively with other agencies and institutions. "Charcoal Production, Marketing and Use" — a joint publication with the Southeastern Forest Experiment Station and the Forest Products Laboratory — summarized 4 years of research in this field. In addition during the year a satisfactory carbonizing method has been developed for slabs, edgings, and factory waste. Some further work may be done on carbonizing low-grade wood waste for use as a heat source.

A practical production technique, now used by one commercial pole producer on several thousand building poles, was developed in the Station's cooperative research with the University of Minnesota. The objective is to improve the serviceability of wood through preservative treatment and improved design of the structures. Wood poles are seldom, if ever, straight. Even the better quality poles used in buildings must often be cut into or shimmed when attaching purlins and girts. To increase the quality of the poles used in several experimental buildings, first the part of the peeled and seasoned pole that was to remain above ground line was placed in a jig to determine its straightest side, then the pole was lightly slabbed with a regular circular saw — from the top to ground line — along this surface. Actually only a light slab was removed, leaving a good nailing surface without notching and shimming. Most of the difficulty of aligning poles was eliminated.



James T. Morgan
Chief, Forest Economics
and Recreation

LARGER MARKETS for forest products are often cited as a major goal in the economic development of the northern Lake States. Faced with declining employment in the mines and in agriculture, this area looks to wood products and outdoor recreation as the basis for developing a stable economy. Much general and spe-

cific information is available on factors that influence increased timber marketing, but rarely can the interested person find all that he wants in one source. A new Station project is a series of studies to establish a factual basis to evaluate increased opportunities for manufacturing and marketing wood products. The area chosen is northeastern Minnesota. The project, which is under the direction of Dr. Dean N. Quinney, is expected to require 1 to 2 years, but interim results will be forthcoming as the studies move forward.

Progress was made on the study of the economic results of red pine management under the direction of Dr. Allen L. Lundgren. Over 600 red pine value-yield tables have been developed for determining the influence of markets, forest sites, stand densities, rotation ages, establishment costs, and interest rates on management decisions. Maximum soil expectation values are being used as the criteria for such decisions. These values have been computed from the value-yield tables and other factors, with the use of a new electronic data computing program.

The study of farm lumber consumption in central Minnesota counties was concluded with the publication of two papers. One, published by the University of Minnesota, describes actual findings in the Survey area. The second, published as Station Paper No. 93, describes the method used and proposes improvements.

Following a custom of several years' standing, forest economics researchers from the Lake and Central States Stations and several universities in the North Central Region met at the Kawishiwi Field Laboratory in June for a 2-day discussion of economics problems and study procedures.

In recreation research, a second summer of fieldwork in the Boundary Waters Canoe Area provided added information on the distribution of recreational use and confirmed some results of the first summer's work. Fieldwork and analysis on this study are now complete, and the report is being prepared. Some of the interesting items that have shown up to date are:

1. The number of visits per year is considerably higher than had been estimated and is increasing very rapidly.
2. The total man-days of use are less than previous estimates because the average length of stay is shorter. A large number of people stay on the area's fringes and enter it by day for fishing and sightseeing.
3. Visitors are highly concentrated in some places, while other attractive areas are seldom visited.
4. Except for a few of the very heavily used access points, people do not seem to object to overcrowding. Crowding seems to be as much or more a problem of mixing incompatible recreation activities as one of numbers of visitors.

With the Universities of Minnesota and Wisconsin, the Station took part in organizing a seminar on recreation research at Madison in May. Results of this conference, which was attended by forestry and social science researchers throughout the Lake States and Ontario, were published in Station Paper No. 89 entitled, "Outdoor Recreation in the Upper Great Lakes Area."

For long-range planning of recreational facilities, the demand for recreation must be related to social characteristics that can be estimated for future populations. During the year David A. King, a forest economist, joined the Station to do research in the analysis of demand for outdoor recreation as related to income and other characteristics of the user population.

Under the leadership of Clarence D. Chase, inventory fieldwork for the third Forest Survey was completed in Minnesota except for three counties in the northeast. The remaining field work will be done in 1962, with the Superior National Forest and the Office of Iron Range Resources and Rehabilitation taking most of the plots. Computing is under way. The second Survey of Illinois was begun in September.

Forest resource reports were published for Wisconsin and Nebraska. "Wisconsin's Forest Resources," Station Paper No. 90, is a summary and interpretation of data from the second Survey of Wisconsin, made by the Wisconsin Conservation Department in cooperation with the Station.

The Station and its cooperators finished a comprehensive canvass of Lake States primary wood-using industries in 1961. The Minnesota data will be used to compute the volume of timber removed from the State's forests in 1960 as a part of the third Minnesota Forest Survey.

Working with the Wisconsin Conservation Department, the Station studied the relationship of a proposed new forest land classification system for tax assessment to the market value of a sample of recently sold forest properties. It was found that the classification, which was based on species, tree sizes, and density of stocking, had little correlation with sale prices. Evidently other values such as recreational uses, which were not measured, are affecting prices of forest lands. This is consistent with the results of ownership studies which show that timber production is seldom the primary objective of small private owners. It points up some of the difficulties in the assessment of forest lands where large areas of timber are taxed on a basis that is not related to the timber-growing potential of the land.

James E. Sowder
Chief, Station Management

Early in 1959 a new Division, Station Management, was established to handle the organizational and research services common to the needs of all the research divisions and Station administration. Its objectives are three-fold: (1) to improve business and personnel management, (2) to provide a more effective publications and information service for both professional and nonprofessional users of the research results of the Station, and (3) to provide editorial, statistical, data processing, library, and other services to research scientists. Its goal is to free project scientists from nonresearch activities and to otherwise assist them wherever possible in their research programs.

Of special interest during 1961 has been assistance given in: expanding the use of electronic computing and data-processing machines, adding speed and versatility to this important aspect of the research job; helping in Station reorganization designed to give greater emphasis to research projects; and recruiting skills needed for expansion of basic research. Excellent progress has also been made in the Station's training and safety program. But perhaps the Division's greatest contribution to future research has been the major role it played in the development of new research facilities as mentioned in the Director's introductory remarks.

All of these activities will continue in 1962. Special effort will be made toward completing new research facilities now under way and strengthening our library and information services.

FOREST IMPROVEMENT RESEARCH

The Wisconsin Forest Resource report, published this year, is the last of the State reports on the second Forest Survey in the Lake States. Data in the Wisconsin, Michigan, and Minnesota reports present the most accurate and detailed picture ever obtained of our timber resource. Comparison with the results of the survey in the thirties shows how the forests are changing. With these new data, the time seems opportune for examining the present status of our forests and considering the research being done to correct their deficiencies and to reverse undesirable trends.

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FIGURE 1. — A striking change in Lake States forest stands over the past several decades has been the increase in the volume of pole-size material. Many stands, such as the aspen shown here, have greatly increased in merchantable volume as they have grown into larger pole-size diameter classes.

Because our forests are mostly second-growth natural stands in the sapling and pole stages of growth, a large part of timber management at the present time consists of timber improvement activities. Specifically this includes investigation into the means of improving tree and stand quality, hastening growth, obtaining better size-class distribution and species composition, eliminating low-quality species and cull trees, and converting forest types to others better suited to the site.

But timber production is not the only objective in managing this young forest. Improvement of wildlife habitat, recreational opportunities, and the quality and amount of water are important aspects of forest management. These must therefore be considered by forest owners and managers when planning timber improvement work.

The following material touches briefly on the present condition of the forest and then discusses the Station's forest improvement research. Major results obtained in past work are explained and the direction of present research indicated. Because forest protection and regeneration studies were presented rather fully in recent annual reports, they are mentioned here only briefly. More complete information on work in these fields may be found in the 1957 (reforestation) and 1959 (protection) annual reports.

Present Forest Stands

When compared to Lake States forest conditions in the middle 1930's, the present stands show many signs of improvement. Although commercial forest area and sawtimber volumes are approximately the same, total timber volume and growth are on the increase. Many changes have taken place in tree sizes and species distributions. In this period the forests have furnished an average annual cut of 560 million cubic feet of products for industrial and home use. The estimated total cut in the years 1936 to 1960 — 14.1 billion cubic feet — is more than half the total growing stock volume of

1936, and today we have more timber than we did then.

In terms of numbers of trees the stocking of forest land has improved. This is a generalization that covers a multitude of changes, both beneficial and otherwise. For instance, in 1936 sapling and seedling stands, which have little or no merchantable volume, covered over 24 million acres. Now the area is reduced to less than 19 million acres, and there has been a more than 50-percent increase in the area of pole-timber stands (fig. 1). The reduced area in sapling and seedling stands is now better stocked with commercial tree species. Present distribution of commercial forest area by stand-size class as compared to 1936 is shown in the following tabulation.

Stand-size Class	*1936*[1] *(Million acres)*	*Present (Million acres)*
Total commercial forest area	53.1	52.6
Sawtimber stands	7.1	7.2
Poletimber stands	10.4	16.3
Seedling and sapling stands	24.4	18.9
Nonstocked area	11.2	10.2

[1] *Data were adjusted to conform to the definitions used in the present survey.*

Sawtimber stands occupy about the same amount of area as in the 1930's but the species composition is different: less area in northern hardwoods and more in oak and lowland hardwoods. The nonstocked area has declined only about 10 percent, leaving some 10 million acres still producing mainly grass and brush. This large residual acreage indicates a big planting job still ahead, although on much of it planting is too difficult or uncertain to be recommended.

Species distribution in the developing forests is not always the most desirable for timber production values. For instance, although acreage in the pine types has risen somewhat, there has been an overall net loss in the area stocked primarily by softwoods. The northern hardwood area remains about the same, but average tree size is less and the stands carry reduced proportions of the more valuable species. Much of the area that has become stocked by natural means has apparently been stocked with elm, oak, ash, and miscellaneous hardwoods. Also it appears that much of the 1.3 million acres missing from the aspen-birch type is now dominated by mixed hardwoods. A comparison of 1936 forest type acreages with the present distribution is shown below:

Forest Type	*1936*[1] *(Million acres)*	*Present (Million acres)*
Total commercial forest area	53.1	52.6
Pine	3.7	3.9
Other softwoods	7.8	6.3
Northern hardwoods	8.2	8.2
Aspen-birch	16.7	15.4
Other hardwoods	5.5	8.6
Nonstocked area	11.2	10.2

[1] *Data were adjusted to conform to the definitions used in the present survey.*

The above area changes have been accompanied by shifts in timber volumes. Although total standing sawtimber about equals that of 1936, many of the traditionally preferred species are present in smaller proportions. Published figures for Michigan and Wisconsin show the reduced volume of sugar maple, yellow birch, and hemlock — major components of the old-growth northern hardwood stands. Oak, elm, ash, and other less preferred species have increased in sawtimber volume at the same time that small trees of these species have become established on formerly nonstocked lands. These trends pose problems for forest managers who are striving to up-grade the quality of their timber.

Total growing-stock volume has increased significantly but not greatly since 1936. Hardwood volume is up 3½ billion cubic feet, but softwoods have lost more than 1½ billion cubic feet. The next tabulation shows present softwood and hardwood volumes by States as compared to 1936.

Locality and Species Group	*1936*[1] *(Billion cu. ft.)*	*Present (Billion cu. ft.)*
Lake States		
Softwood	8.4	6.8
Hardwood	15.4	18.9
Minnesota		
Softwood	3.0	2.8
Hardwood	3.4	4.4
Wisconsin		
Softwood	1.8	1.4
Hardwood	5.2	6.4
Michigan		
Softwood	3.6	2.6
Hardwood	6.8	8.1

[1] *Data were adjusted to conform to the definitions used in the present survey.*

As a result of thicker stocking, improved cutting practices, and other factors, Lake States for-

ests are exhibiting a considerable increase in annual growth. During the two decades following 1936, growth rose from 853 million to 1.177 billion cubic feet annually, an increase of 38 percent. The average annual growth rate for any species is, however, well below that found in the better managed stands. It is clear that much greater timber growth can be produced if the necessary investments are made in planting and cultural practices.

Prospects for increasing timber production in the Lake States are enhanced by the sizable area of public and industrial forest lands. Nearly half of the forest area is in public and forest industry ownership. The major portion of these lands has been committed to forest management and, therefore, is readily susceptible to forest improvement techniques.

The third Lake States Forest Survey which is now under way in Minnesota will provide more information than is now available on stand conditions and needs for remedial treatment. In addition to the standard classifications such as forest type, stand-size, and volume density, an area classification is included. This will disclose how well the growing space is being used by the trees occupying it and will identify problems of spacing, cull trees, inhibiting vegetation, and other factors, and indicate treatment needed.

On the basis of present physical conditions the need for applying more advanced forestry techniques is apparent. Prospects for future markets likewise warrant research and application of methods to improve and speed timber growth. The annual timber harvest has been increasing since the thirties desipte a gradual decline in lumber production. Recent estimates place the total annual harvest at over 6 million cords equivalent. With the construction of new pulpmills in recent years and the increased capacity of others, the wood needs of the region are likely to continue on the upswing.

The trend in overall timber production and use is encouraging, but the forest manager needs more information before rational choices can be made on the application of cultural measures to particular stands. Studies currently under way will help guide the decision-making processes when stand improvement projects are being considered.

Release From Competing Vegetation

An almost universal characteristic of wild land is the abundance of weeds (plants in the wrong place) that interfere with the development of more useful plant species. Forest land is of course no exception. Left to nature, stand composition may deteriorate through the suppression and eventual death of desirable reproduction. Or the timber yield may be reduced in value by the presence of a large proportion of trees of inferior quality.

To insure the formation of stands of high-quality growing stock, release measures often are essential. These may involve the selective removal of poorer stems or, where an entire stand of desirable trees is overtopped, an area treatment may be the best way to provide the needed release.

Research with chemical herbicides has resulted in effective means of accomplishing both types of release jobs under Lake States conditions — means which are more rapid and much less costly than the handtool methods formerly used. These methods have had widespread operational use. Included are: (1) the use of foliage sprays of 2, 4-D or 2, 4, 5-T in aerial or mistblower applications for releasing conifers from stands of overtopping hardwoods, (2) the use of esters of 2, 4-D or 2, 4, 5-T in fuel oil for basal sprays, or for cut-bark treatments in frill girdles or in tree injectors to kill unwanted stems, and (3) the use of amine salts of these herbicides in concentrated form or diluted in water for cut-bark treatments. These release measures are described in detail in Agriculture Handbook No. 185 by J. L. Arend and E. I. Roe, published in January 1961.

Release Methods

Basal sprays are an effective means for controlling individual tree stems, especially small ones under 2 to 3 inches in diameter. Chemical frill girdles and tree injectors are more efficient on larger stems. So, although trees of any size can be controlled with basal sprays at any season of the year, their use is seldom practical on stems exceeding 4 to 6 inches in diameter because of the high volume of spray material required. A general purpose chemical formulation for basal sprays on Lake States species is a low-volatile ester containing 12 pounds of 2, 4, 5-T acid equivalent per 100 gallons

of low-grade fuel oil. By volume, this a 3-percent solution when using an ester of 2, 4, 5-T that contains an acid equivalent of 4.0 pounds per gallon (the label on the chemical container should always be checked for acid equivalent before diluting the herbicide). This prescription may be varied for local conditions from 2 to 4 percent depending on the species, size of stems, and season of application. Small smooth-bark trees do not require as heavy applications as do other trees. Kill is most easily effected immediately after full-leaf development. For small trees the stem is thoroughly wetted around the root collar to a height of about 1 foot until runoff collects at the ground line.

Chemical frill girdles are effective for controlling individual stems exceeding 3 to 4 inches in diameter, especially large culls. Small stems, 1 to 2 inches in diameter, may be cut off in chemical frill girdling operations and the stump sprayed with the herbicide mixture to reduce sprouting.

Use of chemical herbicides in the forest for release of timber species may have an impact on other forest values. There may be benefits as demonstrated by the killing back of palatable shrubs, thus bringing browse production within the reach of deer. Thinning out of the forest canopy may permit greater accumulation of snow and encourage infiltration of snowmelt through effects on soil freezing. On the other hand some desired wildlife food plants may be reduced through herbicide treatment. Such side effects need to be taken into account as plans are developed for chemical treatment.

One big release job ahead in this region is the selective control of undesirable and cull trees in the thousands of acres of second-growth hardwood stands. This type of control can be accomplished chiefly with chemicals by basal sprays and cut-bark treatments. Girdling without supplementary chemical treatment may be preferred in removing the larger culls.

A frill girdle is a complete continuous cut or incision through the bark around the base of the tree. This incision should be as close to the ground as can be efficiently managed with an ax or other cutting tool (fig. 2). Chemical formulations can be poured or sprayed into the frill girdles as a separate operation to kill the top portion of the tree and reduce sprouting. The general herbicide prescription for frill girdles in the Lake States is a low-volatile ester containing 1 to 2 pounds of 2, 4, 5-T acid equivalent per 100 gallons of low-grade fuel oil. By volume, this is a 1- to 2-percent solution when using an ester of 2, 4, 5-T containing an acid equivalent of 4.0 pounds per gallon. The frill girdles should be filled with this herbicide mixture.

Another herbicide that can be used in frill girdles in nonfreezing weather is an amine salt of either 2, 4-D or 2, 4, 5-T. The choice depends on the species. The amine salt of 2, 4-D (4 pounds acid equivalent per gallon) works well on oak and aspen with applications of ½ to 1 ml. per 3 inches of circumference, while tests on other Lake States species show that the 2, 4, 5-T amine at the same concentration is more effective. These amine salts appear to translocate better, especially laterally, than the esters when applied to cut surfaces. For stems up to 6 to 8 inches in diameter, amine salts (containing 4.0 pounds acid equivalent per gallon) may be applied in undiluted form, or, if preferred, diluted with an equal part of water, to the frill girdle in sufficient quantity to wet the bottom of the incision completely around the tree. This requires only about 1 ml. per 3 inches of circumference. More volume should be added for trees 12 to 16 inches and larger.

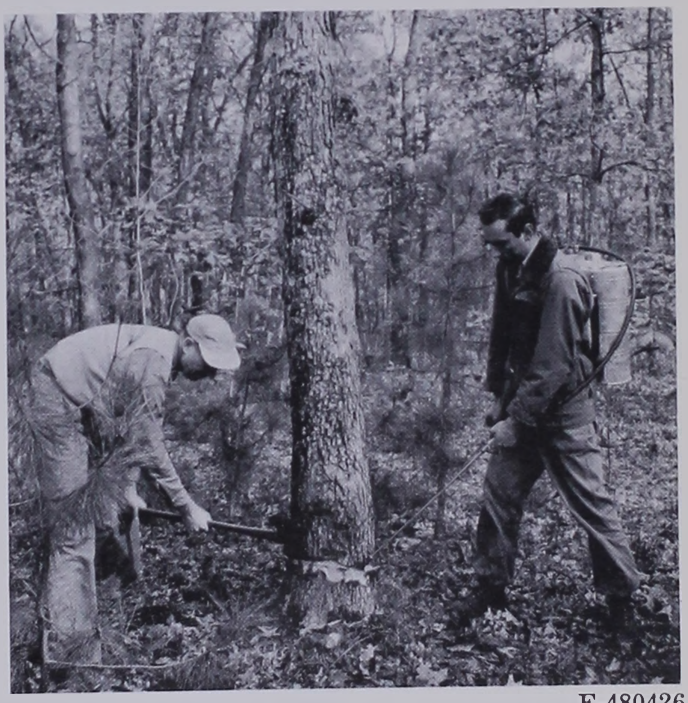

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FIGURE 2. — Applying low chemical frill girdle for pine release.

Chemical frill girdles have been found to be effective on most Lake States hardwoods of all sizes except large sugar maple and hickory. Most research in this region has been conducted on trees less than 12 inches in diameter, but occasional frill-girdle tests on large oak, elm, and beech have shown that they are readily killed when the volume is increased with increasing size of the tree. The ratio of herbicide volume to tree size has not been fully explored.

Tree injectors are hollow tubes, about 2 inches in diameter and 4 to 6 feet long, with a sharp cutting head or bit on one end. This cutting bit makes an incision 1½ to 2 inches wide. By thrusting it downward into the bark, a cut similar to a frill girdle is made around the base of the tree. The chemical carried in the tube is injected into the cut surface on each jab. Such instruments have been used for over 30 years for injecting various chemicals into trees. Recently tree injectors have been made that hold about 1 gallon of herbicide. These tools are rapidly finding favor over two-step chemical frill girdling, especially on small stems, by applying more concentrated herbicide solutions into partial or incomplete frill girdles. This speeds up the treatment time. Tree injectors place the chemical close to the root collar for better sprout control, are safer to use than an ax, and are especially fast for treating small trees with less than 4- to 6-inch diameters. Their main disadvantages are initial cost of the tool and frequent refills.

Since the volume of herbicide applied by tree injectors varies with the brand of the tool as well as with the spacing of the injections, it is difficult to prescribe a general herbicide mixture. However, results from partial frill-girdling tests indicate that 20 pounds of 2, 4, 5-T acid equivalent per 100 gallons of low-grade fuel oil, when applied in volumes to fill the cut incision, will kill the tops of most small Lake States hardwoods when the injections are placed so that untreated areas between injections do not exceed 1 inch. This is a 5-percent solution by volume when using a herbicide containing 4.0 acid equivalent per gallon. Small oak, aspen, elm, basswood, and maple up to 4 to 5 inches in diameter have been easily killed by this method. Larger oak up to 12 inches in diameter may also be killed. During nonfreezing weather an amine salt of 2, 4-D or 2, 4, 5-T diluted in water at concentrations similar to the oil-ester mixtures is also effective. The 2, 4-D amine is as effective on oak and aspen as the 2, 4, 5-T. Where there is a mixture of species including considerable oak and aspen, a 50/50 mixture of 2, 4-D and 2, 4, 5-T amine may be used to reduce costs of the herbicide.

The best combination of herbicide concentration and the spacing arrangement of partial frill girdles need to be further studied for various tree species and sizes in this region.

Foliage herbicide sprays are used for area control treatments. In many stands of both natural and planted conifers, trees overtopped by brush or undesirable hardwoods are so numerous that elimination of the competition by individual stem treatment, even with herbicides, would be too laborious and too costly. For such areas, an overall treatment with herbicides is much more feasible.

Such treatment consists of foliage applications of solutions of 2, 4-D or 2, 4, 5-T, or sometimes mixtures of these chemicals, depending on the species of brush or trees that need control. These sprays can be put on either from the air or with hand or power equipment used on the ground.

The general principles involved in foliage spraying, the pros and cons of the different types of equipment used in application, and the amounts of herbicide materials needed to control different brush conditions are covered in detail in Agriculture Handbook No. 185.

The Station has continued testing specific prescriptions for the control of common species of brush. The prescriptions for the control of hazel have been fairly well worked out and are the subject of an article to be published in the near future. The studies show that:

1. Hazel brush can be much more readily controlled with 2, 4-D than with the much more expensive herbicide silvex (2, 4, 5-TP). Earlier work showed 2, 4-D to be as effective as 2, 4, 5-T and at half the cost for herbicide.
2. For best top kill and least resprouting, the 2, 4-D should be applied when shoot growth is complete but before the leaves have hardened. In northern Minnesota, this stage is usually reached in mid-July.
3. The 2, 4-D should be applied at the rate of 2 pounds of acid equivalent herbicide per acre.

Effectiveness of the herbicide decreased in a straight line as concentration was lowered.

4. For ease of application, the 2 pounds of 2, 4-D should be applied in 2 gallons of water solution per acre. Equally effective control can also be obtained when this amount of herbicide is applied in 4 gallons of water per acre, but this will increase application costs considerably.

These recommendations were worked out with equipment that applied all of the herbicide solution to the foliage. In aerial spraying, therefore, compensation will have to be made for losses due to drift (fig. 3).

Girdling may be used to remove cull trees that utilize growing space and contribute nothing to timber yield. Retention of culls may be justified on other grounds but certainly not on the basis of wood production. Heart rots are more prevalent in hardwoods, so cull removal usually is a hardwood problem.

The beneficial effects of cull removal obviously are dependent on the number of culls and on other conditions of the residual stand. Means of classifying this relationship have not been developed. However, the benefits can be quite large. For example, in a test area where a study of cull girdling was made, timber growth during the 5 years following treatment was increased 25 percent.

Girdling northern hardwood culls with a power saw has been found to be three times faster than with an ax. The average girdling time with a power saw was ½ man-minute per square foot of basal area compared to 1½ man-minutes per square foot with an ax. There was no difference in killing effectiveness between these two treatments.

These were the results from a test of cull-tree removal in northern Wisconsin where 290 trees were girdled, half of them with an axe and half with a power saw. Tree diameters in this stand of mixed poletimber and sawtimber ranged from 6 to 30 inches at breast height. Girdling time for trees with these diameters ranged from 0.2 to 2.4 man-minutes per tree with the power saw and from 0.6 to 6.9 man-minutes per tree with the axe. These figures refer to the actual girdling operation only

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FIGURE 3. — Aerial application of herbicide is simulated in this hazel brush study plot. Spray is applied at top of enclosure. Polyethylene sheeting prevents drift.

and do not include time for rest, tool maintenance, or walking between trees. When these variables were included, the average treatment time per tree was 2.3 man-minutes with the power saw and 6.1 man-minutes with the axe.

In another cull-removal study we found that the time required to fell pole-sized culls was about the same whether using a hand saw or a power saw. Other requirements of the study precluded valid estimates of actual production rates, but conditions were the same for both tools and the comparative result should be real.

Growth Response After Release

Growth response after release adds increment to the residual stand. Although it has long been known that the removal of overtopping or competing trees is characteristically followed by increased growth on the more valuable ones, the full meaning of this benefit is seldom stressed (fig. 4). Not only does such release produce more volume growth, but there is also the added advantage of earlier production of quality materials. Thus, a stand of pine 25 to 30 years after release may have a fair to good volume of sawlogs, while an adjacent stand of pine and hardwoods of the same age but not released will have all or most of its volume in the form of pulpwood.

This is demonstrated by what has happened since release on three separate stands at widely separated locations in northern Minnesota. One of these is a red pine plantation with two degrees of release, the second is natural white pine with two degrees of release, and the third a stand of mixed red pine and white pine with only moderate release. The understory pines ranged from 18 to 35 years of age when released and have since had 18 to 25 years of growth.

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FIGURE 4. — A 53-year-old mixed stand of red and white pine 18 years after release from overtopping aspen and other hardwoods. Recovery has been good, and growth has greatly increased. Of the total cubic-foot volume on this plot, 97 percent is now in high-value conifers.

Since all show essentially the same growth pattern, only the data from one of the stands, the Birch Lake plantation at Ely, are given here. (See also pp. 35-36 of the Station's 1960 Annual Report.)

TABLE 1. — *Effect of plantation release on volume growth, Birch Lake Plantation, Ely, Minn.*

Time of measurement and species	Sawtimber volume when degree of release is —			Pulpwood volume when degree of release is —		
	None	Moderate	Full	None	Moderate	Full
	Thousand bd. ft.	*Thousand bd. ft.*	*Thousand bd. ft.*	*Cords*	*Cords*	*Cords*
Immediately after release at age 19:						
Red pine	0	0	0	0.8	0.9	0.6
Aspen	0	0	0	1.6	0.1	0.0
All	0	0	0	2.4	1.0	0.6
22 years after release:						
Red pine	3.5	8.8	10.8	17.6	26.3	34.2
Aspen	1.5	0.2	—	13.1	5.8	1.1
All	5.0	9.0	10.8	30.7	32.1	35.3

Assuming an average value of $25 for red pine saw log stumpage the sawtimber on the full-release plot is worth $270 compared to $220 on the moderate release and only $87.50 per acre where no release was done. Obviously, the release has effectively stimulated the production of both sawtimber and pulpwood.

Other points made by these release studies are: (1) Complete release gives the best results, and (2) release is cheapest and most effective when done very early in the life of the plantation or natural stand.

All species do not benefit equally from release. Studies have shown that white pine growing under an overstory of hardwoods is less susceptible to white-pine weevil attack. This is due in part to the thin-barked, small-diameter leaders produced under competition. White pines growing in the open produce large-diameter, thick-barked leaders that are favorable oviposition sites for this weevil. The same condition may be experienced with jack pine. Under some conditions, therefore, release may need to come gradually over a period of years, or it may need to be delayed until additional height growth takes place. These are problems for which there is no cut and dried solution.

Precommercial Thinning

Many problems encountered in the management of even-aged stands can be traced to early stand history. If the juvenile stand was excessively dense or open, if the trees were clumpy in distribution, if species composition was undesirable, or if individual trees were diseased, crooked, or otherwise defective — all of these conditions are reflected in the appearance and value of the stand as it grows older. Remedies can best be applied while the stand is still young. The cost is less, and growth thereafter is put on good trees. After an untreated stand reaches commercial size, the value of the thinning products may be lower and the difficulty of timber-sale administration greater because of an unfavorable early stand history.

Natural Jack Pine

Precommercial thinning can often be done in natural jack pine with considerable advantage to the forest owner. One such example can be found in a 280-acre tract on the Aurora District of the Superior National Forest in northeastern Minnesota (fig. 5).

The jack pine originated from regeneration of a portion of the Palo-Markham burn, which occurred in 1936. The catch of seedlings in many areas exceeded 10,000 stems per acre. At age 5 a precommercial thinning experiment was installed, with the jack pine thinned to the following spacings in feet: 4x4, 6x6, 8x8, and an unthinned control. The experiment was repeated three times.

The latest measurements have recently been analyzed. Some of the characteristics of the stand at age 23 are given in table 2.

Several general statements can be made about the results of the precommercial thinning described above.

1. Wider spacing invariably results in faster diameter growth, larger branches, and a shorter rotation (if size is a controlling factor).
2. Closer spacing generally results in greater volume production at young ages and higher qual-

TABLE 2. — *Some results 18 years after precommercial thinning in a jack pine stand now 23 years of age*

Item	Spacing between trees in feet			
	Unthinned	4x4	6x6	8x8
Number of trees per acre	3060	1940	1070	640
Average tree diameter — inches	2.8	3.6	4.5	5.2
Average tree height of dominants and codominants—feet	33	33	33	33
Average branch diameter — inches[1]	([2])	0.32	0.43	0.53
Total cubic feet per acre[3]	1670	1890	1590	1280
Total cordwood per acre[4]	6.3	13.0	14.1	12.0

[1] *Average diameter of branches 3 inches from bole in a section of tree from 6 to 12 feet above ground. All branches in this section were dead on all trees.*
[2] *Not measured.*
[3] *Peeled volume of all stems 0.6 inch d.b.h and larger.*
[4] *All stems 3.6 inches d.b.h. and larger to a 3.0-inch top d.i.b.*

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FIGURE 5. — A dense stand of jack pine 10 years of age. In places, over 10,000 per acre survived to this age.

ity trees (better form and smaller branches), but will increase establishment costs and delay the first commercial cut.

3. Spacing will not affect height growth within the range of sites and stocking levels normally encountered. However, on very poor sites close spacing may cause a reduction in height growth.

The vast amount of literature now available concerning spacing in young stands would indicate that these general statements apply to most species of pine.

Stocking levels also may have entomological implications. For example, heavy staminate flower production is associated with high budworm populations. Since studies indicate that more staminate flowers are produced in the denser stands, there is more possibility of budworm attack in unthinned timber.

Plantations

The spacing at which trees are initially planted also has a major influence on the early growth and development of plantations. The effect on growth is roughly proportional to the distance between trees.

Plantations at spacings of 5x5 feet or closer or those in which volunteer stocking has caused a decrease in growing space will usually benefit from precommercial thinning. These thinnings should begin before the green crowns constitute less than 50 percent of the tree height. The expected results from such a thinning are shown by a study established in 1954 in a 15-year-old jack pine plantation that had been planted at different initial spacings.

During the 5 growing seasons after treatment the diamater growth response was roughly proportional to the degree of thinning. The trend of increasing diameter with increased growing space is shown in figure 6. These trends indicate that future thinnings can be postponed until commercial-size products can be cut without a serious reduction in rate of growth. Although no cordwood volume has yet been produced, some material will become merchantable soon in the wider spacings. In the unthinned plots, however, the slower rate of diameter growth makes it doubtful that any merchantable material will be produced in the near future. These results show that at least 7x7-foot spacing is required for satisfactory development of the trees.

Similar effects of close spacing have been reported in red pine, white pine, and Norway spruce on a gravelly sand soil that formerly supported red and white pines. At 41 years of age with densities of 5,000 to 8,000 living trees per acre, the average diameters of the dominant trees ranged from 2.6 inches for Norway spruce to 3.5 inches for red pine. Even after years of extreme close spacing, branch stubs persist on all species and no merchantable cordwood volume has developed. Precommercial thinning would still be feasible in this stand because of the excellent response of these species to increased growing space. However, with proper initial spacing precommercial thinnings should be unnecessary in plantations of the Lakes States.

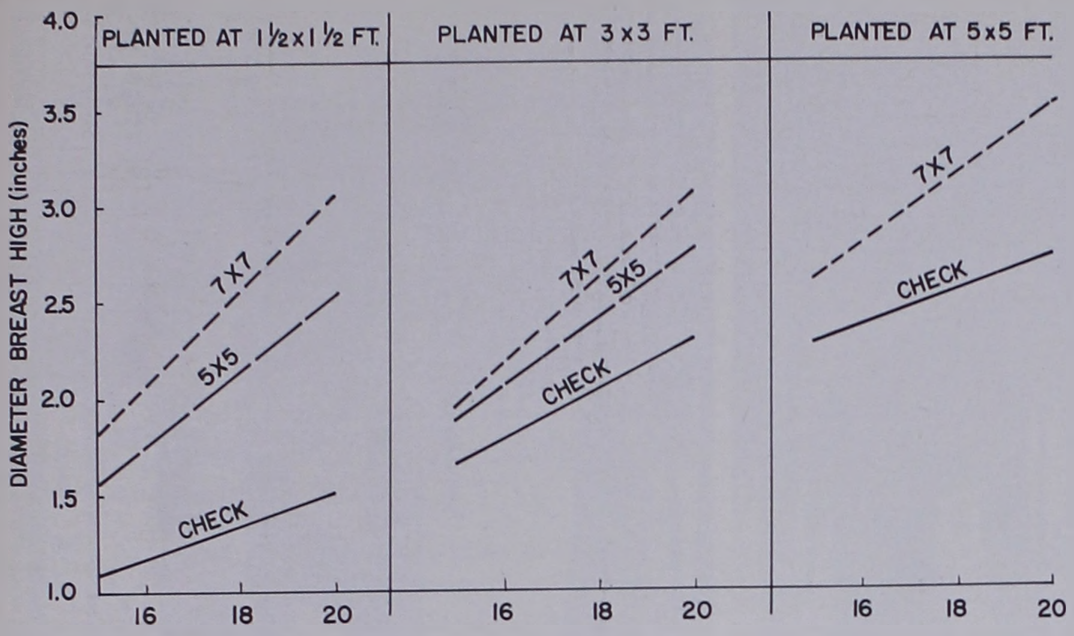

FIGURE 6. — 5-year diameter growth response of 15-year-old jack pine to non-commercial thinning at different spacings.

Northern hardwoods

Several million acres in the Lake States are covered with northern hardwoods of submerchantable size. A question often asked about these stands is: Should precommercial treatments be made? Anticipating the need for such information, the Lake States Station initiated a study in sapling-sized hardwoods in 1938.

The stand chosen for this study was even-aged and consisted of trees averaging about 2 inches d.b.h. and 20 feet tall. There were about 3,000 trees per acre, and 300 to 400 of these were chosen for crop trees. Two thinning intensities were tested. All competitors were cut within a 2½- or 5-foot radius of the crop trees. Ten years later, the crop trees in each of these two treatments received additional release by increasing the thinning radii to 5 and 7 feet respectively.

Twenty-year growth records show that the thinned stands contain slightly less cubic-foot and cordwood volume than unthinned stands. However, the important point is that thinning shifted the growth to the crop trees. Without thinning only one-half of the volume was in crop trees. After the heavier thinning slightly less than four-fifths of the volume was in these more desirable stems.

Early thinning increased crop-tree diameter growth (fig. 7) and decreased mortality. In general, diameter growth was proportional to degree of release. Tolerant species such as sugar maple showed greater response to release than did intolerants such as ash and basswood. Mortality was heaviest in the smaller diameter classes. Nearly twice as many trees died on the control plots as on the thinned plots.

Trees that were dominants and codominants at the time of the original treatment proved to be the best choice for crop trees. Natural dominance was expressed early, and selection of crop trees in the upper crown classes usually insured that such dominance would be maintained, especially when thinning treatments were applied. Relatively few intermediates moved into the higher crown classes even after heavy release.

The success of precommercial thinning cannot be judged upon tree growth alone. In fact, tree quality may have an even more important effect upon final dollar yields. Early thinning increased diameter and height growth but decreased average merchantable height. Low forks are more common on thinned plots. Forks below 25 feet occurred on 65 percent of the elm, 40 percent of the ash, and 37 percent of the maple in the most heavily thinned plots. On the unthinned plots, low forks in these species occurred on only 38, 28, and 27 percent of the stems respectively. Thus increased growth due to early thinning has been offset by a decrease in individual tree quality.

The development of epicormic branches follow-

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FIGURE 7. — Comparison between thinned and unthinned basswood clumps only 8 years after treatment. In the unthinned clump, the three largest stems are 5.0, 3.6, and 3.5 inches in diameter. The trees in the thinned clump (*right*) are 7.7, 6.5, and 5.3 inches in diameter. The contrast between these two clumps was even greater 20 years after treatment.

ing precommercial thinning was related to intensity of treatment. The heavier the release, the more prolific the epicormics. Persistence of epicormic shoots on dominant trees was only temporary. About half of the thinned dominants had epicormic branches 2 years following the second release, but now these shoots occur on less than 4 percent of the residuals. However, persistence of these shoots on crop trees in other crown classes is more important. In the codominant crown class, one-fifth of the heavily thinned trees, one-tenth of the lightly thinned trees, and one-twentieth of the unthinned trees still bear epicormic shoots. Occurrence of epicormic shoots in the intermediate and suppressed crown classes ranged from 50 to 75 percent.

Commercial Thinning

The practice of thinning even-aged coniferous timber in the Lake States has become commonplace only since World War II. It is applied primarily to jack pine, red pine, and white pine stands. Other even-aged types including uniform pole stands of northern hardwoods, are still not commonly thinned. Intermediate cuttings do more than control stand density: They control quality and spacing of individual trees, and in some cases they change the species composition of the stand. Furthermore they may affect the susceptibility of the stand to injurious insects and diseases, or modify the environment for wildlife.

Hardwoods

Many second-growth stands of mixed northern hardwood sawtimber and poletimber will support a merchantable intermediate cut. Some of the larger trees can be cut for saw logs and the smaller stems thinned out for pulpwood or chemical wood. If there is no market for the smaller trees, it is usually advisable to girdle or chemically treat the

undesirable stems to permit the better ones to develop.

Growth data in relation to stand density are only sufficient to provide a general guide to treatment of mixed sawtimber and poletimber. The general recommendation is to leave a residual stand of 85 square feet of basal area per acre in trees 5 inches in diameter and larger. Above this stand density there usually is sufficient volume to allow a commercial intermediate cut. More important, this treatment will leave the stand in condition for optimum growth without sacrificing quality. Heavier cuts may result in the development of sprouts and epicormic branches.

The same recommendation applies to even-aged poletimber stands. However, because of the limited markets for small hardwoods, stand treatments will usually be of an investment nature. Such cultural treatments should be warranted because of the potential high value of the final crop.

Aspen stands rarely are given a commercial thinning. This is true even though growth response of the residual trees is favorable. The principal reason for this lack of interest in thinning may be the large volume of mature aspen available for clear cutting. In addition borer damage has been found more severe in less dense stands. Intermediate cutting tends to increase borer infestation. Even periodic removal of infested trees may be worse than no cutting until final removal of the mature stand. In the absence of borer attack, thinning on the better sites should improve board-foot production.

Conifers

The question of proper growing stock density has received much more study in conifers than in hardwoods. Growing stock density experiments at the Lake States Station go back to 1926. By comparison with present-day standards, the earlier studies show little contrast between densities. As new experiments have been installed, the range has increased. The most recently installed red pine studies contain density levels of 30, 60, 90, 120, and 150 square feet of basal area per acre plus unthinned controls.

During the past year, three of the older red pine experiments have been remeasured and analyzed. These were placed in 40- and 80-year-old timber at the Cutfoot Experimental Forest in 1949 and in 50-year-old timber at Bena, Minn., in 1955

FIGURE 8. — A view of a growing stock density experiment in 55-year-old red pine. This stand was cut to 80 square feet of basal area 5 years previously.

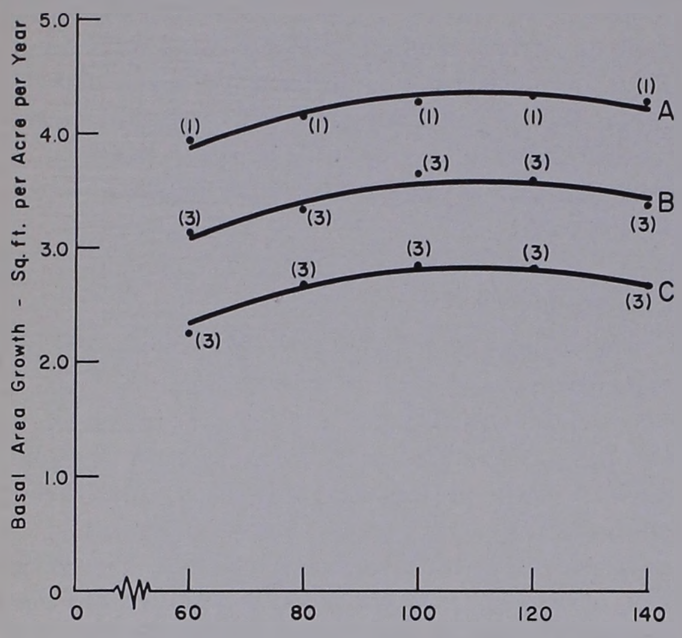

FIGURE 9. — Basal area growth of three red pine growing stock density experiments in Minnesota. Stand A, 40-year red pine; Stand B, 50-year red pine; Stand C, 80-year red pine. Figures in parentheses indicate number of observations for each experiment.

(fig. 8). All are on medium site and have density levels ranging from 60 to 140 square feet of basal area. The 40- and 80-year stands have been remeasured twice at 5-year intervals, and the 50-year stand once.

The basal area growth curves show remarkable agreement in shape among the three experiments. There is surprisingly little difference in basal area growth at any of the density levels (fig. 9).

Curves for cubic-foot volume growth rise as densities increase (fig. 10). A careful examination of plotted points would suggest that this rise is most pronounced in the 40- and 50-year-old stands, although statistical methods used in curve fittings were unable to detect a difference between the three experiments. Cordwood growth for the 40- and 50-year stands traces a pattern very much like the curves for cubic-foot growth. Board-foot growth also follows a pattern like cubic-foot volume growth except that ingrowth distorts the picture somewhat.

Thinnings in dense natural red pine pole stands also tend to be beneficial from a watershed viewpoint. In late winter and early spring, thinned stands show a greater depth of snowpack, a higher total water content (with an assumed greater ground water recharge), less depth of soil freezing, and slightly earlier snowmelt.

Another aspect of commercial thinning is its potential effect on insect outbreaks. For example, in spruce-fir it is generally agreed that stand condition has a considerable influence on the development of spruce budworm epidemics. Preliminary results from cutting studies in northern Minnesota to test the influence of stand density indicate that partial cutting reduces the severity of budworm attack.

Plantations

The regular spacing of plantations encourages rapid development of the trees when they are young. How soon planted stands take on the growth

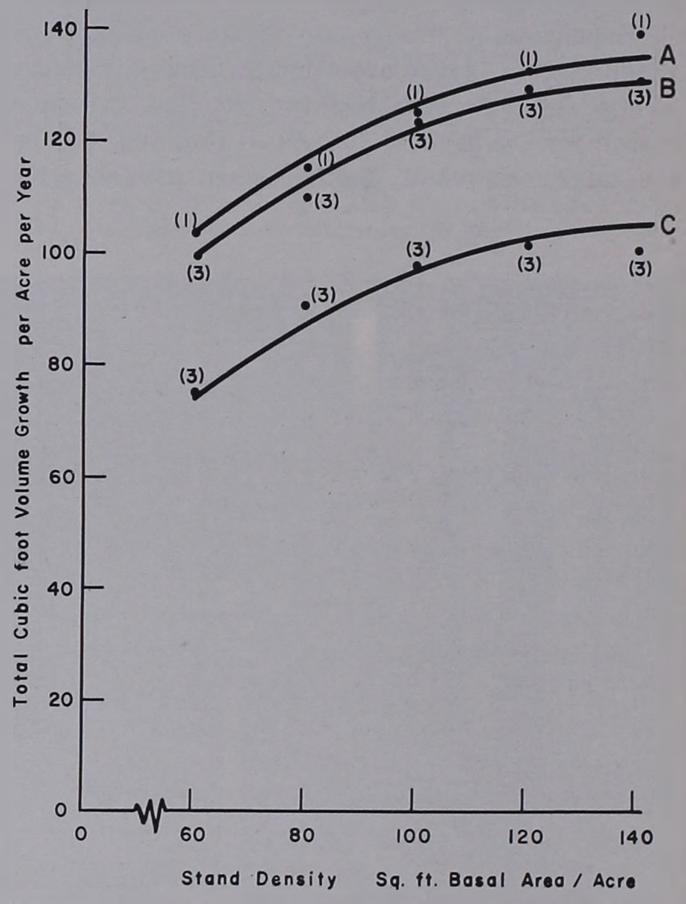

FIGURE 10. — Total cubic-foot volume growth of three red pine growing stock density experiments in Minnesota. Stand A, 40-year red pine; Stand B, 50-year red pine; Stand C, 80-year red pine. Figures in parentheses indicate number of observations for each experiment.

characteristics of natural stands is unknown. Long-term observations are developing the answer. Meanwhile, information on stand density effects and the results of intermediate cutting are being developed specifically for plantations. These studies show that a wide range of stocking will give satisfactory cordwood growth but also indicate limitations within which thinnings should be made to provide for quality growth and development of larger sized trees.

The first thinning is perhaps the most important one as it usually occurs within the period of most rapid growth in the life of the stand and it provides an initial selection of the final crop trees. The first thinning should, therefore, begin before competition appreciably reduces stem growth. Because this stage varies to some extent by species, site productivity, stand age, and original spacing, reliable indicators are (1) the amount of basal area, (2) proportion of the stem in living crown, and (3) the rate of diameter growth.

In young red pine and white pine plantations, current basal area growth is reduced after basal area stocking reaches about 140 to 160 square feet per acre, the higher level generally occurring on the more productive soils. At this density the proportion of the stem in living crown averages about 55 per cent of the total height. With closely spaced plantations, however, the living crown may be only 45 to 50 percent. If crown length is reduced below these percentages the early growth response to release will be slow.

Intolerant species, such as jack and Scotch pine, seldom attain basal area stocking of 140 to 160 square feet until time for the harvest cut and then have much lower live-crown ratios at these stand densities. Their current basal area growth begins to decline after the stands reach 90 to 110 square feet of basal area on the medium sites. At the time thinning should be started, which varies from 25 to 35 years depending on site quality and initial spacing, mortality is still light and there is little differentiation into crown classes. Diameter growth usually shows a steady decrease in width of annual rings.

Ten-year growth results from red pine plantations first thinned in 1951 and rethinned in 1956 and 1961 show that satisfactory cubic and cordwood volume growth was obtained over a wide range of residual stand densities. The primary difference between the stands has been in the amount of growth that is related to site index, original spacing, and stand age. Because of the flatness of the growth curves, the point of maximum volume growth is not sharply defined (fig. 10). This permits a wide latitude in thinning to meet different product and quality objectives. Good basal area and cordwood growth rates have been maintained with basal area levels of 80 to 140 square feet per acre. Thinnings to leave only 60 square feet show no appreciable loss in cordwood volume growth, and levels of 160 square feet show only slight reductions. Board-foot volume growth, however, tends to decrease with increase in basal area stocking.

During the 10-year observation of red pine there have been no major differences in growth due to method of thinning. The basic method has been thinning from "below" coupled with removal of deformed trees of all size classes. Thinning from "above", in which the largest trees are removed to a predetermined stocking, has given the lowest basal area and cordwood volume growth for comparable levels of stocking. However, the amount of growth has been increasing after each thinning, indicating the improvement in crown development on the smaller residual trees.

Mechanical thinning has been tested in red pine plantations originally spaced at approximately 4x5 feet. Cutting every other row and every third row both showed excellent 10-year growth response. Cordwood growth has averaged slightly over 1.8 cords per acre per year on this medium site in comparison to 1.7 cords for thinning from below. The good response to row thinning is attributable in part to the release of every tree and the continued expression of dominance within the uncut rows. Additional tests of this and other methods of thinning have been installed in recently established replications.

Other factors that may affect the choice of a residual basal area level or method of thinning are changes in stem form, amount of lower branch dying, and ultimate size of the product desired. During a 10-year period following thinning from below in a red pine stand in Lower Michigan it was found that diameter growth at both 4.5 and 17.0 feet decreased with increasing basal area, but there was

little change in the taper of the stem over a wide range of residual basal areas. Diameter growth at 17.0 feet exceeded that at 4.5 feet at stand densities above 160 square feet of basal area per acre but occurred at about the same rate at densities between 90 and 140 square feet.

Dense stands would appear to favor natural pruning and the production of clear wood. Although branches below a dense forest canopy die from shading, in red pine the stubs persist for many years. Artificial pruning is necessary for production of clear wood in the stand rotations feasible under intensive management. At 60 square feet of basal area per acre the height to live crown remains relatively constant. Between 140 and 160 square feet branches at the base of the crown die at a rate sufficient to maintain a constant live crown ratio. At 200 square feet the lower branches die rapidly, causing a progressive reduction in proportion of tree height in live crown.

The effect of growing space on red pine diameter growth is shown in the following tabulation for an average site:

Basal area (square feet per acre)	*Average growth 100 largest trees (inches)*
60	2.8
100	1.9
140	1.3
200	1.3

The increased individual tree growth in thinned plantations, is attributable to greater availability of soil moisture as was brought out in a study in the sandy soils of Lower Michigan. Elimination of root competition and reduction of crown interception generally increased the amount of available moisture. Effects in winter were similar to those in natural conifer stands that have been thinned, i. e., greater snow catch and less depth of ground freezing, thus permitting infiltration of more water into the soil. This increase in soil moisture resulted in more rapid growth and, for the more heavily thinned plots, a longer growing season. In regions with frequent dry years, lower stocking levels should yield a higher rate of growth.

Soil-Site Relationships

Several million acres of forest land in the Lake States that once supported fully stocked stands of mixed pine and hardwoods are now taken over by oak, aspen, and mixed hardwoods. The stands are poor in quality and sparsely stocked. These less desirable stands have been produced by clear cutting followed by repeated fires. Natural conversion to more productive species is slow. Although a sizable portion of this acreage is suitable for purposes other than timber production, much of the sparsely stocked area can be improved by partial or complete planting to conifers. Other plantable areas have only a grass or brush cover.

In order to decide on whether planting of this land is justified and, if so, which species are suited to the site, a great deal should be known about the relationship of tree survival and growth to topography and soils. This is a subject which has been continuously under investigation for a number of years. Insect or disease relationships may be significant, as for example the recent finding that the better the site the less severe the infestation of European pine shoot moth on red pine.

General guidelines have been developed for predicting survival and early establishment on broad soil groups. These are adequate for some purposes. Where soils have been classified for agricultural use the soil series and phases can be a help. Local guides are available in a number of areas. In general, jack pine and Scotch pine are superior to other species on the coarse sandy soils. Red pine, white pine, and white spruce develop best on the finer textured and heavier soils .

Predicting survival and successful early establishment of a planting requires much less precision than estimating ultimate yield of wood. For the latter purpose the general guides are less satisfactory. However, decisions on the desirability of stand conversion or of planting open land revolve around this question of productivity. Clearer definition of the characteristics of topography and soils that can be identified with measurable differences in tree growth is needed for all species and timber types.

Site Quality of Aspen Lands

Acreage-wise the most critical problem related to interpretation of soils in terms of tree growth is the 19 million acres of aspen in the Lake States. In general, growth of aspen is poor to fair on sands and light loams and good to excellent on the

heavier loams. Repeated fires, cutting, insects, diseases, and storm damage may complicate the picture.

Efforts to work out a scheme for predicting the site quality of aspen lands from topographic and soil features have been only partially successful. An example is the procedure worked out in Station Paper No. 86, "Evaluating the growth potential of aspen lands in northern Minnesota", by R. O. Strothmann. Errors of estimate for the predicted values are larger than would be desirable in a fully satisfactory classification. This is true of similar classifications for aspen and for many other species. However, as information and experience accumulate, the errors of estimate are reduced.

Type Conversion

Converting from one cover type to another presents some difficulties, as illustrated by a study of techniques for planting red pine as a replacement for oak in Lower Michigan.

Here tests were made of machine-planting versus hand-planting before and after cutting the overstory. Red pine was machine-planted before cutting at a density of about 700 trees per acre in a low-quality northern oak stand containing about 65 square feet of basal area. Placement of the trees was generally good, with most trees being planted in openings and far enough from stumps to avoid immediate competition from resulting sprouts.

Half the losses caused by subsequent cutting were attributed to repetition of trips on skidding trails down planting rows. Damage by falling trees and piling of slash in the natural openings accounted for most of the remainder. Where single loads were skidded over the pines they were seldom injured. Directional felling should decrease damage, and scattering the slash should result in fewer injuries than piling it in open areas. Survival and growth since cutting have been good.

Planting after cutting was more difficult because the openings were filled with slash. Tree placement was poorer because more of the pine were planted closer to the stumps, and competition, tending to suppress height growth, occurred much earlier. When planting is done after cutting, hand

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FIGURE 11. — Typical aspen culls 1 year after they were killed by 2,4-D applied from the air.

planting will generally be necessary to obtain satisfactory stand densities.

Although about one-half of the northern oak stumps sprouted after cutting, the rate of sprout growth was slow. With proper tree placement release work can often be delayed until the planted pine are well established and able to take immediate advantage of more growing space.

In past years the artificial conversion of aspen stands to conifers, while possible, was not practicable because of the high cost. Although conifers could be underplanted in most stands, release from low brush and from the overtopping aspen was a costly and difficult problem.

Recent work done by the Station with chemical herbicides, however, should completely change the aspen conversion picture, for it has been found that the addition of more 2, 4-D to the solutions commonly used for the aerial control of hazel, willow, and alder brush will take care of large aspen culls as well. Although this approach has not yet been used in the artificial conversion of aspen stands, it has been successfully used to free 80 acres of dense understory balsam fir from aspen culls on the Superior National Forest. This job was done at a cost of about $6 per acre (fig. 11). No further investment will be necessary as the balsam fir is too tall and too dense to suffer from competition from either brush or aspen suckers.

Present indications are that conversion from inferior aspen or oak to conifers will also influence the water behavior of the area. Dense plantations increase interception especially of snow, decrease soil moisture, and increase depth of soil freezing. (This points out another advantage of wider spacing or early thinnings in plantations. This practice benefits both timber growth and snow-water accumulation.) Conifer plantings also tend to delay snow-melt by a week or two. A greater proportion of pine stands in our aspen forests would thus help delay the simultaneous release of snow-water from a large area and could conceivably reduce peak flows. Management practices that encourage conversion of pure aspen to mixed conifer-hardwoods are most desirable hydrologically. This condition catches more spring snow-water and retains it longer than either pure hardwoods or conifers.

Timber Quality

Northern Hardwood Pruning

Under existing market conditions, improvement of timber quality is a major silvicultural consideration in the northern hardwood type. To a large extent, quality depends on the limb-free length of the bole and the number, arrangement, and character of over-grown limb stubs or knots. Quality can be controlled, to a degree, through stand density, but under more intensive silvicultural practice, a positive means of improving individual tree quality is desirable. Preliminary studies indicate that pruning will provide positive control of limb-associated defects in sugar maple, American elm, and yellow birch.

As shown in figure 12, scars resulting from artificial pruning on sugar maple and American elm generally heal over within 4 years after pruning. The rate of healing seems to be very slightly affected by wound size up to about 2 inches in diameter. On pruned yellow birch trees, however, healing rate is positively correlated with both wound size and growth rate (fig. 13).

In other respects, the three species react to artificial pruning in a similar manner. Branch stubs projecting as little as one-fourth of an inch beyond the bark increase the healing period by 1 to 3 years. On intermediate and suppressed trees in thinned stands the limb-free advantage of pruned trees is likely to be nullified by the development of epicormic branches around the pruning wounds. On dominant and codominant trees these branches either do not develop or do not persist.

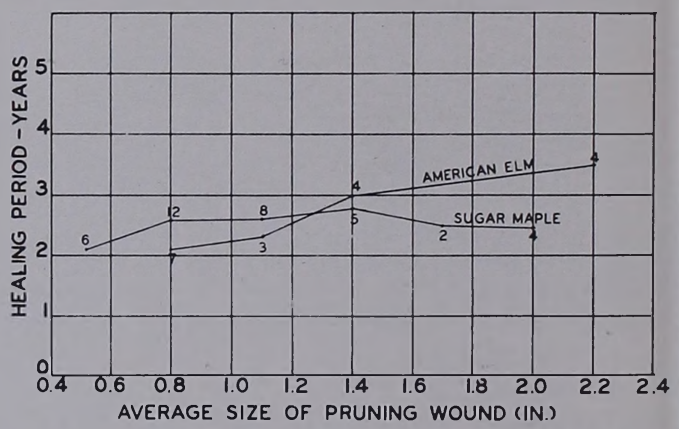

FIGURE 12. — Period required for pruning wounds of various sizes to heal American elm and sugar maple (data combined by 0.3-inch classes).

Dissection studies of many pruning wounds show that heart-rotting fungi usually do not enter the bole through the wounds. Sap rots were present in the stubs of many limbs that were dead when pruned, but these did not affect the overlying clear wood. Long, unsound branch stubs, ingrown bark, and local decay pockets were associated with branches removed by natural causes. When branches are removed artificially these defects are either eliminated entirely or limited to a relatively small central core.

All these results lead to the conclusion that pruning, properly applied, can increase the proportion of clear wood in individual sugar maple, yellow birch, and American elm trees. To be most effective, pruning should be limited to trees in the upper crown canopy, and branches must be pruned as close to the bole as possible, but pruning wounds should not exceed 2 inches in diameter.

There has been no attempt to quantify the effect of pruning on ultimate stand value. It seems very likely that the most promising application will involve removal of a few branches to upgrade the quality of individual trees in otherwise poor-quality, even-aged stands.

Conifer Pruning

The quality problem in conifers is most evident in plantations. There, quality of products harvested is largely determined by stem diameter and the size and number of knots. The regular spacing of plantations tends to limit knot size. But the dead branches usually persist for many years on the species most commonly planted in the Lake States (fig. 14). Improvement of quality in these stands can be achieved most rapidly through a combination of thinning and artificially removing the lower branches. Without pruning, few trees will be marketable for the more valuable log grades, poles, and veneer stock which the 2 million acres of plantations in the Lake States are capable of producing.

Pruning studies substantiate the economic feasibility of pruning plantation-grown species where growth can be increased by thinning. At least a 3- to 8-percent compound interest rate can be earned on a pruning investment over a 60-year growing period by hand-pruning methods. With the advent of power equipment greater returns may be possible.

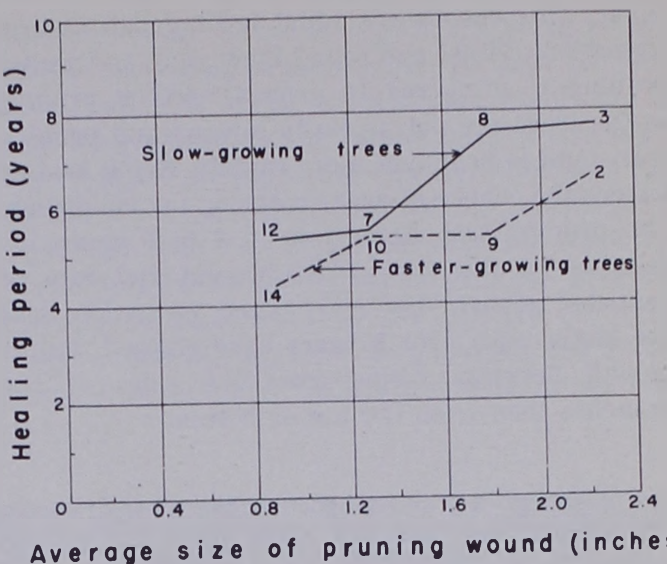

FIGURE 13. — The influence of wound size and tree-growth rate on wound healing of artificially pruned yellow birch. Wound size was determined by measuring the vertical diameter of the pruning wound; data were combined by 0.4-inch classes. The "slow-growing trees" had an annual radial growth of between 0.04 and 0.09 inch; the faster growing trees, 0.10 to 0.20 inch.

To realize these values plantation trees should be pruned when they are about 20 to 25 feet tall. Trees 30 to 40 feet can be pruned but with a lower rate of economic return. Generally 50 percent of the total tree height can be pruned without causing a reduction in growth of the tree. Removing more than one-third of the live crown during the initial treatment will usually retard the rate of diameter growth. In a closed 25-year-old plantation on average sites the trees can be pruned to approximately 10 feet in the first operation without removing more than one or two living whorls. Later the height of pruning can be increased to about 12 feet and then to a one-log length of 17 feet to keep the size of the knotty core at a minimum. This three-step method is usually the most economical. Delaying pruning until the trees are about 35 feet tall to permit pruning to a height of 17 feet in one operation is less desirable because of the increase in size of the knotty core, although it too can be a profitable operation. Rarely will it be desirable to prune to a height greater than one 16-foot-log length. The pruning time per tree averages about 9.1 minutes for the one-step method and 10.0 minutes for the three-step method.

All pruning should be flush with the tree boles without damaging the bark adjacent to the branch

collar. This encourages rapid healing and assures formation of tight and sound knots. Fall and winter pruning is preferred to growing season pruning as the trees are not as easily injured and pruning scars tend to heal over more rapidly. Rapid healing lessens the chance of decay entering the main stem. The pruning scar heals over in 3 to 5 years, depending on the size of the wound and rate of diameter growth, but clear wood formation does not begin until 6 to 8 years have elapsed. Callus growth develops faster from the sides of the branches than from the top or bottom.

The number of trees that should be selected for pruning varies with the product objective and potential value, but generally from 75 to 150 trees per acre should be pruned. These should all be dominant trees of good form with average size or smaller branches. The pruned trees should be well spaced so they will not be taken out in future thinnings. They will make up the final harvest. With special markets for evergreen boughs or as a fire protection measure, pruning of nearly all trees may be justified.

More intensive pruning in which one whorl of

FIGURE 14. — Unpruned 40-year-old white pine plantedat a 4x5-foot spacing. Note the persistence of dead branches. (Photo courtesy of Michigan Department of Conservation.)

branches or the lateral buds are removed each year is not recommended for the pines in the Lake States. With this method pruning begins when trees are 6 to 8 feet tall and all but the top one or two whorls are removed. The initial treatment is followed by annual or biennial branch pruning until a clear length of 17 feet is obtained. Although this method results in the smallest knotty core, it causes a serious reduction in diameter and height growth. In general, annually pruned trees are more susceptible to stem bending and deformities than conventionally pruned trees, and costs of pruning tend to be slightly higher.

Genetics and Physiology

Quality Control for Seed

Another way to improve our forests is to use better seed in planting and direct seeding work. The seed used may be better than average physically, genetically, or both. In any event a necessary first step is to provide that any seed used is exactly as it is represented to be.

In agriculture, where there is a long history of seed control, two general methods are used: (1) labeling laws and (2) certification standards. Currently there is no federal law in the United States governing tree seed, and only about five States have tree seed labeling or certification laws. There is, however, a growing interest in tree seed control among foresters, Christmas tree growers, nurserymen, and seed control officials.

As an outgrowth of that interest a subcommittee of the Society of American Foresters made a survey of opinion among foresters and seed handlers throughout the United States and Canada. (One of our staff members is chairman of this subcommittee.) This survey indicated enough interest in seed certification to warrant deliberate activities toward that end, brought out some directions as to how these steps should be taken and what ought to be included in certification standards or labeling laws, and showed the desirability of working toward suitable international standards. (See Society of American Foresters Report in the September 1961 issue of the Journal of Forestry.)

Recommendations for minimum seed certification standards were developed following the opinion survey. These standards are being reviewed by interested organizations. If they, or some modification of them, are accepted eventually by the International Crop Improvement Association they will be the minimum (stricter standards can, of course, be adopted) that will be acceptable in any State that has legal provision for certifying forest tree seeds and in which the local crop improvement association is the official certifying agency. Means can thus be provided for giving recognition to better quality tree seed in the market.

Seed Source Variation

We can also improve our forests by developing and planting trees that combine large size, rapid growth, desirable form, and good-quality wood. Unless such trees are hardy in the locality in which they are to be grown, however, possession of these valuable characteristics will be of little importance.

During the course of many centuries, trees adapt themselves to the climatic extremes and to the insects and diseases of the locality in which they are growing. Often a single species grows over a wide geographic range within which climatic and soil conditions vary greatly. As a result numerous local races may have come into being. The individuals of each race often differ very little in external appearance from those of another race, but they may differ considerably in survival and growth qualities. Because of this process of adaptation, it usually is best to plant trees grown from local seed. This is not always true, however. In some places certain races of some species have proved better than local races.

The importance of racial variation was recognized as early as 1926 in the Lake States Station's work program. During that year seed collection was started for a comprehensive study of red pine. A review of this early study when the trees were 18 years old (from seed) showed that trees from the home locality (northeastern Minnesota) on the average produced more total cubic-foot volume than those from any other locality and nearly three times as much as that from the poorest region. However, seven sources from the home locality varied more widely in volume per acre than did the regional averages. The best of the local sources had pro-

6. Larch of 6 origins from Siberia (3 of Siberian Larch, 1 of Dahurian larch, and 2 of a natural hybrid) was field-planted in North Dakota in the spring of 1961.

7. Eastern white pine of 18 origins from Georgia to Nova Scotia and west to Minnesota and Iowa has been studied in the nursery and will be field-planted in the spring of 1962 in five locations in the Lake States. This study has been developed in cooperation with the Ontario Department of Lands and Forests and the Northeastern, Southeastern, and Central States Forest Experiment Stations who also have outplantings.

8. A range-wide variation study in white spruce includes 28 collections covering the territory from Maine to Montana and Labrador to Alaska. This material has shown considerable variation in the nursery and will be outplanted in the spring of 1962 in five localities in the Lake States and in some other regions. Stock from 15 western sources will be planted in North Dakota. This study is supplemented by a field planting in Upper Michigan of white spruce from 13 Canadian sources.

9. Another study of white spruce aims to test whether distinct races have evolved as a result of climatic diversity in the Upper Peninsula of Michigan. Included are 27 stand collections from Upper Michigan and, for comparison, two from Lower Michigan and one from northeastern Wisconsin. Nursery and greenhouse tests are underway.

10. In the spring of 1962 stock from 11 sources of Norway spruce from Russia, Siberia, and the Baltic countries will be planted in northern Minnesota and North Dakota.

All these studies will help to outline the amount of genetic variation within the major tree species grown in the Lake States and the suitability of various races for specific localities. They will provide the raw material for interracial hybridization, possibly the most promising avenue for genetic improvement of our tree species and they will also furnish material of known origin for interspecies hybrids.

Selection of Superior Trees

Much of the possible improvement of forest trees, however, depends upon the recognition and utilization of superior stands and of individual tree variations. This is a second step after racial variation is determined, but it can and should be carried on concomitantly.

In this field the Station is carrying on two kinds of activities, as follows:

1. Station genetics personnel have assisted National Forest and State conservation department foresters in the selection and marking of some 40 superior stands (chiefly red pine and white spruce) to be used as seed production areas. Guidelines for this work were prepared by the Station.

2. Through the cooperation of foresters of public and private agencies the Station is assembling a register of superior or unusual trees in the Lake States. Guidelines for selection were prepared by the Station, and final selection of the trees is made by Station genetics personnel. So far about 70 selections have been submitted but all have not yet been screened.

These activities should eventually lead to a tree breeding program that will produce trees more productive and more hardy than those we now have and especially suited for particular conditions in the Lake States and Northern Plains.

Physiology of Xylem Formation

Without a better understanding of the growth processes in individual trees, improvement of the forest will be more difficult. Several years must elapse between the time a tree seed germinates and the development of many of the outward characteristics determining its desirability as growing stock. Fundamental knowledge can provide a shortcut for this waiting period.

To accomplish this purpose we are first attempting to gain a thorough understanding of the technical characteristics of wood as they are related to the processes that govern their development. Research already underway at the Station, coupled with a careful review of a great many publications on various aspects of wood quality, makes it clear that best progress will ensue if we have a unifying concept by which all the individual factors affecting wood quality may be related to the overall growth of the tree. This is not a new idea. One of the first serious students of wood quality, the forest botanist Robert Hartig,

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FIGURE 15. — Variation between two seed sources of Norway spruce after 15 growing seasons in the field. Photo at left shows trees from a source near Bryansk in the U.S.S.R.; this shows a wide variation in height but the trees average 9 feet tall. Below are trees from a source near Belgrade in Yugoslavia; vigor is poor and average height is 5 feet.

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duced seven times as much wood as the poorest one. Some sources from other seed collection regions had produced more wood than some local sources. These findings point out the need for thorough testing of our important species both on a range-wide and on a more local basis.

To that end the Station established other seed source studies in the 1930's for Scotch pine, European larch, green ash, white spruce, and Norway spruce. Some of these studies included only a limited number of sources, and parts of them were destroyed by catastrophes such as drought and fire, but they have indicated racial variation in the species and have provided material for further study (fig. 15).

Since 1954 there has been renewed emphasis on forest tree improvement research at the Station, and the following racial variation studies have been undertaken:

1. A regional jack pine seed source study conducted in cooperation with the University of Minnesota and several other public and private agencies includes 29 collections from the Lake States planted in 17 localities within the region in 1954. Significant differences due to source are already evident.

2. Eastern hemlock of 19 seed origins throughout its range was planted in northeastern Wisconsin in 1958. Source-related differences in frost hardiness have been observed.

3. Red spruce from 14 localities ranging from North Carolina to Nova Scotia was planted in northeastern Wisconsin in 1960.

4. Blue spruce of seven origins throughout its range from Arizona to Wyoming was planted this spring (1961) in North Dakota under shelterbelt conditions.

5. Scotch pine of 33 origins in the U.S.S.R. (26 in Siberia) was field-planted in the spring of 1961 in North Dakota, Nebraska, and Saskatchewan (the last two by cooperators). Stock of 24 lots was also planted in northeastern Wisconsin. In Lower Michigan Scotch pine of 109 origins throughout its range was planted in the spring of 1961 in cooperation with Michigan State University.

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never lost sight of the concept of the tree as a biological whole as he attempted to explain all wood growth and quality in terms of various physiological processes.

In discussing wood quality primary emphasis usually is placed upon variations in the proportion of earlywood to latewood, since this is the most obvious feature of wood growth and development. Percentage of latewood and the associated changes in cell dimensions determine to a large extent the specific gravity of the wood. Although the wood quality factors contributing to specific gravity are not always highly correlated with the arbitrary values for latewood percentage, they do vary in a more or less predictable pattern across the growth ring. Thus, cell diameter and length, cell wall thickness, micellar angle, and chemical constituents of the cell wall, all vary positionally within the "normal" tree in a reasonably predictable and regular manner (fig. 16).

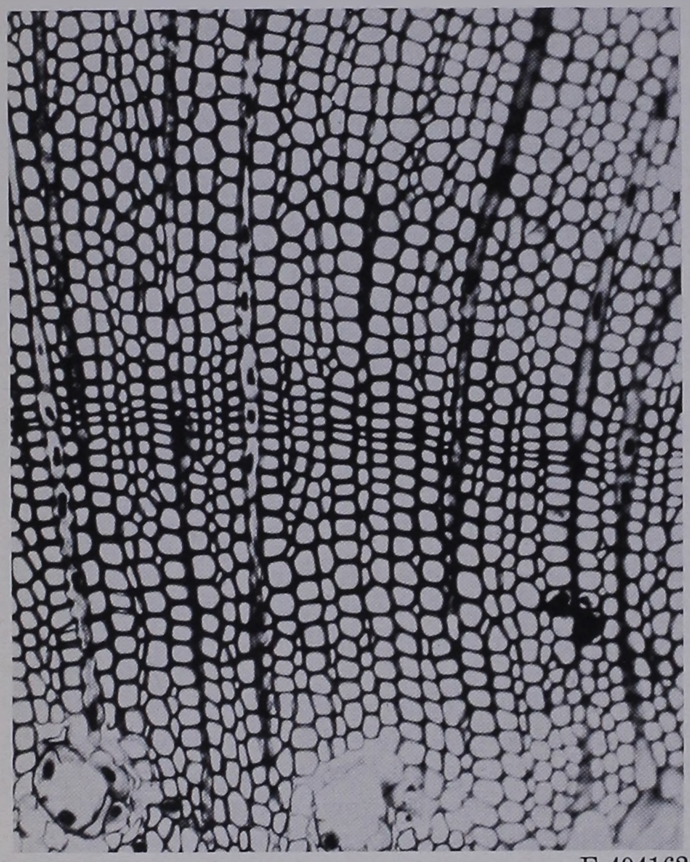

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FIGURE 16. — Conditions that cause shoot growth to cease during the normal period of elongation result in the production of narrow-diameter xylem cells. The false ring in this photograph was produced by a 3-week short-day treatment of young red pine followed by a long-day treatment. The short-day treatment caused cessation of elongative growth with attendant production of small-diameter cells; and the subsequent long-day treatment brought about a renewal of apical activity and large-diameter cell production.

All variations in wood quality are believed to be reflections of crown growth. It must, of course, be recognized that all parts of the tree, including the wood of the trunk, are dependent upon the crown as well as the roots for the basic products of growth. Emphasis here, however, is not on these fundamental physiological and biochemical growth processes, but on the final products of growth and wood quality that can be measurably and often visibly altered by the external environment.

In summary, it is evident that the basic patterns of variation of the wood quality factors are undoubtedly controlled by heredity, but they can, and do, also vary with stand structure, site conditions, geographic locality, and other growth conditions that make up the environment. The direct effect of environment is primarily on the growth processes of the crown and only indirectly on the growth of the xylem. The amount and distribution of wood growth on the stem are determined to a large extent by crown size and distribution; in the normal course of competition within a forest stand these crown values are relatively stable and are altered slowly with time. The proportion of earlywood to latewood and the quality or structure of the wood within the growth ring, on the other hand, are determined by seasonal fluctuations of the environment that influence crown growth and may vary quite rapidly with time. These are, of course, generalizations but, with present knowledge, the quality of wood that a particular forest stand will produce can be predicted with reasonable accuracy if the history and growth conditions of the stand are known.

However, it is not possible to project the values obtained from one forest stand to other stands and forest conditions without similar information concerning the environment. The numerous interactions that occur in nature make it impossible to predict wood quality by rules of thumb, such as rate of growth, that will cover all growth conditions. Nevertheless, by considering wood quality in terms of crown growth and development, the variations due to stand structure, site, and to some extent geographic locality and heredity, can be re-

conciled and the general trends of wood quality interpreted.

Now, how can this background of knowledge about wood quality, present and future, be put to use by the silviculturist? For one thing, he can plant trees of such proveniences, selections, or hybrids as are known to have inherently high-quality wood. This can be done both in establishing new stands and in "sweetening" existing stands. Secondly, by understanding that the crown is not only the source but also the regulating center responsible for all wood growth, he can manipulate the stand and some features of the site to influence both the quantity and quality of wood desired on various parts of the tree bole. Such practices as thinning, pruning, fertilizing, drainage, and insect and disease control all can be employed to this end under specific circumstances. As research develops more detailed knowledge about wood growth and quality, the silviculturist should be able to utilize it in exercising more precise control of these attributes.

LIST OF PUBLICATIONS, 1961

LAKE STATES FOREST EXPERIMENT STATION

General Forestry — *Order No.*

Olsen, L. P. SP 39—Sup. 1*
LIST OF PUBLICATIONS OF THE LAKE STATES FOREST EXPERIMENT STATION, 1956-1960. U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 39, Sup. No. 1, 67 pp. (Processed.)
(Station publications during 1956-1960 are listed, and each item has a brief annotation describing contents.)

Scholz, Harold F. R 261
REVIEW OF "THE VEGETATION OF WISCONSIN" BY JOHN T. CURTIS, 657 PP., ILLUS., 1959. Jour. Forestry 59:30.

U. S. Forest Service, Lake States Forest Experiment Station. 1960 ANNUAL REPORT. (No series), 68 pp., illus. R 235*
(Describes briefly the new projects, the progress on established projects, and some of the results obtained on studies completed during the year.)

Regeneration, Stand Improvement, and Harvest Cuttings

Arend, John L. R 252
AERIAL APPLICATION OF HERBICIDES FOR RELEASE AND CONVERSION. In Proc. Forestry Symposium: Herbicides and Their Use in Forestry. Pa. State Univ., Aug. 30-31, 1960, pp. 118-123.
(Aerial application of herbicides has extensive use in forestry to free conifers from competing broadleaf vegetation. Its main advantages over ground methods are quick coverage, ease of operation in rough, inaccessible forest areas, and low cost. Subjects discussed include formulation of 2,4-D and 2,4,5-T for various species, carriers for diluting the herbicide, rates per acre, timing, types of aircraft used, marking areas to be sprayed, cost, and special precautions.)

Arend, John L. R 253
REVIEW OF "WEED CONTROL: AS A SCIENCE" BY GLENN C. KLINGMAN (EDITED BY LYMAN J. NOORDHOFF), 421 PP., ILLUS., 1961, NEW YORK. Jour. Forestry 59: 903, 906.

Arend, John L., and Roe, Eugene I. AH 185*
RELEASING CONIFERS IN THE LAKE STATES WITH CHEMICALS. U. S. Dept. Agr. Handbook 185, 21 pp., illus.
(Describes various methods of using chemical herbicides to release planted and natural conifers in the Lake States from undesirable hardwoods and brush. General prescriptions are given as to the amount of herbicide and volume of solutions needed to control brush stands of different species, size, classes, and densities.)

Church, Thomas W., Jr. R 238*
THE EFFECTS OF STOCKING LEVEL CUTTINGS ON THE VOLUME AND VALUE OF RESIDUAL TIMBER IN A NORTHERN HARDWOOD STAND. Mich. Acad. Sci., Arts, and Letters Papers (1960 meeting) XLVI: 267-276, illus.
(An old-growth northern hardwood stand was selectively marked and cut to progressively lower residual stocking levels. Results showed that residual volume was related to stocking level, but that proportionate volume in log grades 1 to 3 was almost identical for levels of 50, 70, and 90 square feet. Net board-foot yield per square foot of residual stocking was highest at the 70-square-foot level, and stumpage value per acre declined rapidly below this point.)

Church, Thomas W., Jr. R 233*
FACTORS AFFECTING THE DEVELOPMENT AND SURVIVAL OF SUGAR MAPLE SPROUTS. Soc. Amer. Foresters Proc. 1960: 32-35, illus.
(Sugar maple stumps were examined for sprouting activity from 1 to 5 years following partial cuts. In old-growth stands there was a decrease in percentage of stumps sprouting with an increase in tree diameter, residual stand density, and years since cutting. Number of sprouts per stump also declined with tree size and years since cutting. In second-growth stands, differences were less pronounced.)

Church, Thomas W., Jr. TN 605*
SEASON OF LOGGING UNIMPORTANT IN CREATING DISTURBED SEEDBEDS FOR YELLOW BIRCH. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 605, 2 pp. (Processed.)
(Seedbed scarification is a prerequisite for the efficient establishment of yellow birch seedlings.

**Available for distribution*

Scarification caused by logging was insufficient regardless of season of year. Acceptable seedbed disturbance ranged from 2 percent of the total selectively logged area in the winter to 10 percent in the summer.)

Clausen, Knud E., and Rudolf, Paul O. R 255
SPIRING AF 29 ÅR GAMMELT *PINUS RESINOSA* FRØ. Skovbrugstidende 47 (5): 35, 37.

(Red pine seed stored for 29 years still retained some viability as follows according to place of storage: seedhouse attic, 0.6 percent; fruit cellar, 5.5 percent; and cold room, 6.7 percent. This is a Danish translation of Minnesota Forestry Note No. 72.)

Lohrey, Richard E. TN 607*
STAND DENSITY INFLUENCES STEM TAPER IN A THINNED RED PINE PLANTATION. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 607, 2 pp., illus. (Processed.)

(Stem taper between 4.5 and 17 feet increased at a density of 60 square feet per acre and decreased at densities above 140 square feet per acre. At densities from 100 to 140 square feet there was little change in stem taper.)

Rudolf, Paul O. TN 598*
1960 FOREST TREE SEED CROP GENERALLY GOOD IN THE LAKE STATES. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 598, 2 pp. (Processed.)

(Seed crops for the principal forest tree species are listed in percentage of a full crop for northern Minnesota, northeastern Wisconsin, central Upper Michigan, Lower Michigan, and north-central North Dakota. Although reports varied from species to species and locality to locality, this was generally one of the best forest tree seed crops produced in the Lake States since annual reports began in 1946.)

Watt, Richard F. R 263
ARTIFICIALLY EXTENDED PHOTOPERIOD INCREASES SIZE OF NURSERY STOCK. Univ. Minn. Forestry Note 104, 2 pp., illus. (Processed.)

(Use of incandescent light to extend the natural photoperiod in a Wisconsin nursery to 20 hours resulted in increased growth of white and red pine and white and black spruce during the first 2 years from seed. Height of spruce was doubled by the treatment, indicating possibility for use in commercial nurseries.)

Tree Improvement

Arend, John L.; Smith, Norman F.; Spurr, Stephen H.; and Wright, Jonathan W. R 239*
JACK PINE GEOGRAPHIC VARIATION — 5-YEAR RESULTS FROM LOWER MICHIGAN TESTS. Mich. Acad. Sci. Arts, and Letters Papers (1960 meeting) XLVI: 219-238, illus.

(Two seed origins from the western part of Lower Michigan grew significantly faster than any others included in the test. Next were two provenances from the eastern part of Lower Michigan, then several from Wisconsin and Minnesota, and last, four provenances from Upper Michigan. The latter were about 20 percent shorter than those from Lower Michigan. Significant differences among provenances were also found in the susceptibility to bark beetles, white-pine weevil, and sawfly, but not in earliness of cone production, resistance to other pests, or oak-pine gall rust.)

Batzer, H. O. TN 595*
JACK PINE FROM LAKE STATES SEED SOURCES DIFFER IN SUSCEPTIBILITY TO ATTACK BY THE WHITE-PINE WEEVIL. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 595, 2 pp. (Processed.)

(Fifth- and sixth-year measurements of trees from 30 seed sources in a jack pine plantation near Cass Lake, Minn., showed significantly more weeviling in sources from Pine County, Minn.; Douglas, Burnett, Marinette, Oneida, and Wood Counties, Wis.; and Gogebic County, Mich., than was observed in the local source. No source had significantly less damage than the local stock.)

Kozlowski, Theodore T., and Cooley, John H. R 256
NATURAL ROOT GRAFTING IN NORTHERN WISCONSIN. Jour. Forestry 59: 105-107, illus.

(Intraspecific root grafting was observed in sugar maple, red maple, yellow birch, white birch, white pine, red pine, balsam fir, eastern hemlock, and northern white-cedar. Grafting appeared to be the result of diameter growth pressure and was most prevalent in stony soil. No true interspecific grafting was observed, although roots were often so closely associated that the growth of callous tissue gave the appearance of a graft.)

Larson, Philip R. R 251*
INFLUENCE OF DATE OF FLUSHING ON FLOWERING IN *PINUS BANKSIANA*. Nature (London) 192 (4797): 82-83.

(Four-year-old jack pine trees were brought into the greenhouse at four different dates in early spring to test the theory that time of flushing may influence flower initiation. Pronounced differences in the number of both male and female flowers were noted for the various dates.)

Nienstaedt, Hans. R 237*
INDUCTION OF EARLY FLOWERING — A CRITICAL REVIEW OF RECENT RESEARCH. (Abst.) Vol. II, Ninth Internatl. Bot. Cong. Proc. (1959): 283.

(A distinction is made between flower induction — the induced production of flowers in material in a juvenile stage of development — and flower stimulation — the artificial augmentation of flowering in plants already capable of producing flowers. With this definition in mind, it is suggested that flower induction through common methods such as ringing and root pruning is likely to be ineffective. A call is made for basic research on auxin metabolism and photoperiod in relation to flowering.)

Nienstaedt, Hans, and Olson, J. S. R 236*
EFFECTS OF PHOTOPERIOD AND SOURCE ON SEEDLING GROWTH OF EASTERN HEMLOCK (*TSUGA CANADENSIS* (L.) CARR.). Forest Sci. 7:81-86, illus.

(Thirty seed sources were grown under controlled photoperiods and thermoperiods. They showed a distinct clinal variation pattern in their responses, but this does not exclude the possibility of relatively abrupt genetic changes either on a broad or local geographic scale. A "critical" photoperiod for vegetative growth was determined to be 15 to 16 hours. Best growth was obtained at alternating temperatures, with 27° C. day and 17° C. night being near the ideal.)

Rudolf, Paul O. R 260*
COLLECTING AND HANDLING SEEDS OF FOREST TREES. U. S. Dept. Agr. Yearbook 1961: 221-226, 552-557.

(Condensed information for important North American forest tree species on time and methods of seed collection, types and processes of extraction, cleaning methods and extraction factors, kinds and effectiveness of storage, pretreatment methods for overcoming dormancy and nursery sowing rates for species groups. Appendix table gives data for 86 species on seed production, weight, dormancy, and germination.)

Rudolf, Paul O. R 259
SELECTING CONIFER SEED PRODUCTION AREAS IN THE LAKE STATES. *In* R-9 State Nurserymen's meeting (Proc.) 1961: 2-12. Region 9, U. S. Forest Serv., Milwaukee. (Processed.)

(Guidelines are given for the selection, development, and maintenance of seed production areas in red pine, jack pine, white pine, white spruce, and black spruce stands in the Lake States. Probable seed costs and future activities (seed orchards) are mentioned.)

Rudolf, Paul O., *et al.* R 243*
SOCIETY OF AMERICAN FORESTERS REPORT ON A STUDY OF SEED CERTIFICATION CONDUCTED BY THE COMMITTEE ON FOREST TREE IMPROVEMENT. Jour. Forestry 59: 656-661.

(A nationwide survey of opinion made by the SAF Tree Seed Certification Subcommittee showed a strong majority in favor of some degree of certification for forest tree seeds. Based on these results revised minimum tree seed certification standards were prepared for presentation to the International Crop Improvement Association.)

Soils and Water

Bay, Roger R. R 254
HOW MUCH WATER IN A SWAMP? Conserv. Volunteer 24 (143): 48-51, illus.

(Popular-style article on the experimental swamp watershed now established in northern Minnesota. Precipitation, groundwater fluctuations, and runoff are being measured to determine the hydrologic characteristics of these forested swamps.)

Curtis, Willie R. TN 613*
AN INEXPENSIVE WATER-LEVEL POINT GAGE. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 613, 2 pp., illus. (Processed.)

(Materials and methods of construction of an inexpensive waterlevel point gage are described. The gage is for use in conjunction with streamflow recording stations. Three photographs show general view and specific details of construction.)

Sartz, Richard S. TN 601*
COMPARISON OF BULK DENSITY OF SOIL IN ABANDONED LAND AND FOREST LAND. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 601, 2 pp. (Processed.)

(Soil core samples taken in the same soil type (Dubuque silt loam) under two different land uses showed the effects of land clearing and cultivation on bulk density of the soil. In the natural soil profile under an oak-hickory stand, bulk density in the upper 3 inches was 0.70. In the open land profile it was 1.08. Bulk density in the 3- to 6-inch layer was slightly higher in the forest than in the open, but from 6 to 24 inches there was little difference.)

Sartz, Richard S. TN 612*
THE FOREST-LAND GULLY IN THE DRIFTLESS AREA — NATURAL OR MAN-CAUSED? U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 612, 2 pp., illus. (Processed.)

(To test the theory that the forest-land gully — a common feature of the Driftless Area — has resulted from ridgetop farming, a survey of 40 completely forested drainages was made to check for gullies or other signs of surface flow. Not a single gully or eroded channel was found. Other evidence also strongly suggests that gully erosion was not a feature of the natural landscape.)

Sartz, Richard S., and Curtis, Willie R. SP 91*
FIELD CALIBRATION OF A NEUTRON-SCATTERING SOIL MOISTURE METER. U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 91, 15 pp., illus. (Processed.)

(A method of calibrating the Nuclear-Chicago neutron-scattering soil-moisture depth probe by gravimetric sampling is explained. Soil moisture contents as determined from the manufacturer's calibration curve were found to be too high at low moisture levels and too low at high moisture levels. Correction factors for shallow readings are given for the particular instrument used.)

Stoeckeler, J. H. R 262*
SOIL AND WATER MANAGEMENT FOR INCREASED FOREST AND RANGE PRODUCTION. Soil Sci. Soc. Amer. Proc. 25: 446-451.

(Production of desirable species of forest trees and range plants can be increased through proper application of knowledge of soils and their growth potential. Some of the ways this can be done are: planting the correct species on its most productive site, using commercial fertilizers and nitrogen-fixing crops, removing excess water through drainage, spreading surplus water to the drier sites, and improving soil moisture status through better ground preparation and after-care to keep competing vegetation under control. Estimates are given for acreage in the United States requiring specific types of treatment. An additional growth of 64 million cords of wood per year seems potentially possible.)

Striffler, William D. TN 603*
INTENSITY OF SOIL MOISTURE SAMPLING AS AFFECTED BY DEPTH AND VEGETATIVE COVER. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 603, 2 pp., illus. (Processed.)

(Variability of soil moisture contents under oak and grass cover as revealed by intensive sampling of 1-acre plots during wet and dry seasons show that number of samples required for comparable results will vary by cover type and soil depth.)

Forest Insects

Anderson, Gerald W., and Schmiege, Donald C. SP 88*
THE FOREST INSECT AND DISEASE SITUATION, LAKE STATES, 1960. U. S. Forest Serv., Lake States Forest Expt. St., Sta. Paper 88, 18 pp., illus. (Processed.)

(A cooperative report based on surveys conducted by Federal, State, and private agencies in 1960.)

Bean, James L. R 249*
A METHOD FOR ESTIMATING THE NUMBER OF SPRUCE BUDWORM EGGS PER EGG MASS. Jour. Econ. Ent. 54:1064.

(Presents a table showing the estimated number of spruce budworm eggs per mass based on length of egg mass and number of rows of eggs.)

Bean, J. L. R 244*
PREDICTING EMERGENCE OF SECOND-INSTAR SPRUCE BUDWORM LARVAE FROM HIBERNATION UNDER FIELD CONDITIONS IN MINNESOTA. Annals Appl. Ent. 54: 175-177, illus.

(Studies in northern Minnesota indicate the possibility of calculating from standard thermograph records, using 2.5° C. as the threshold temperature, the degree-hours necessary to establish the approximate date when the first larval emergence will occur.)

Bean, J. L. R 248*
THE USE OF BALSAM FIR SHOOT ELONGATION FOR TIMING SPRUCE BUDWORM AERIAL SPRAY PROGRAMS IN THE LAKE STATES. Jour. Econ. Ent. 54: 996-1000, illus.

(Studies in Minnesota have shown that spruce budworm larval development was closely correlated with balsam fir shoot elongation. With this as a basis, a method was developed for using balsam fir shoot elongation for timing spruce budworm aerial spray programs in the Lake States. Two methods of calculating total shoot growth are presented.)

Bean, J. L., and Prielipp, D. O. TN 602*
INSECT DAMAGE TO WHITE SPRUCE CONES AND SEEDS — A FACTOR IN WHITE SPRUCE REGENERATION. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 602, 2 pp., illus. (Processed.)

(Damage to cones and seeds results in poor seed crops and affects natural and artificial regeneration. Seven species attacking white spruce cones and seeds are discussed.)

Bean, J. L., and Waters, W. E. FPL 58*
SPRUCE BUDWORM IN EASTERN UNITED STATES. U. S. Forest Serv., Forest Pest Leaflet 58, 8 pp., illus.
(Presents the life history, habits, and control of the spruce budworm in the eastern United States.)

Ewan, Herbert G. TB 1250*
THE SARATOGA SPITTLEBUG: A DESTRUCTIVE PEST IN RED PINE PLANTATIONS. U. S. Dept. Agr. Tech. Bul. 1250, 52 pp., illus.
(Presents the results of some 15 years of research on the biology, ecology, and control of the Saratoga spittlebug in red pine plantations in the Lake States.)

MacAloney, Harvey J. FPL 57*
PINE TORTOISE SCALE. U. S. Forest Serv., Forest Pest Leaflet 57, 7 pp., illus.
(A brief account of the life history, habits, and range of the insect, and suggestions for its control and for preventing damage.)

Miller, William E. R 245*
A NEW PINE TIP MOTH (OLETHREUTIDAE) FROM THE GULF OF MEXICO REGION. Jour. Lepidop. Soc. 14: 231-236, illus.
(A pine tip moth new to science is described and named *Rhyacionia subtropica.*)

Miller, William E., and Haynes, Dean L. R 250*
EXPERIMENTS WITH CONCENTRATED DDT SPRAYS FOR EUROPEAN PINE SHOOT MOTH SUPPRESSION IN FOREST PLANTATIONS. Jour. Econ. Ent. 54: 1014-1018, illus.
(The least DDT dosage in mistblower treatments consistently giving 90 percent or more control was 10 pounds of actual toxicant per acre; the least volume 40 gallons of water spray per acre. The period available for applying concentrated sprays for good control in the spring is 1 to 2 weeks.)

Miller, William E., Hastings, Arthur R., and Wooten, John F. FPL 59*
EUROPEAN PINE SHOOT MOTH. U. S. Forest Serv., Forest Pest Leaflet 59, 8 pp., illus.
(Reviews current knowledge about this pest and gives latest prevention and control recommendations.)

Schmiege, D. C. TN 597*
MORTALITY AND TOP KILL AN[illegible] OF SPRUCE-FIR CAUSED BY REPEA[illegible]AR MA[illegible] L[illegible] BUDWORM DEFOLIATION. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 597, 2 pp. (Processed.)
(After at least 2 years of heavy to complete destruction of current foliage by the spruce budworm, mortality and top-killing became apparent. A survey in 1960 revealed top-killing as high as 78 percent and tree mortality as great as 2.4 cords per acre on individual plots.)

Speers, Charles F., and Schmiege, Donald C. FPL 63*
WHITE GRUBS IN FOREST TREE NURSERIES AND PLANTATIONS. U. S. Forest Serv., Forest Pest Leaflet 63, 4 pp., illus.
(The life history of the white grub, including a description of the various stages of this insect, is presented along with information on how damage may be prevented by the use of insecticides.)

Wilson, Louis F. FPL 67*
THE VARIABLE OAK LEAF CATERPILLAR. U. S. Forest Serv., Forest Pest Leaflet 67, 4 pp., illus.
(A brief account of the life history, habits and range of the insect, and suggestions for its control and for preventing damage.)

Wilson, Louis F. TN 596*
GRASSHOPPERS — A MAJOR DEFOLIATOR OF TREES AND SHRUBS IN THE NORTHERN GREAT PLAINS. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 596, 2 pp., illus. (Processed.)
(Several species of grasshoppers, which normally feed on various agricultural crops, attacked shelterbelt trees and shrubs after the crops were harvested. Both defoliation and debarking occurred when infestations were heavy, and conifers and broadleaved species were equally susceptible.)

Wilson, Louis F. TN 599*
CALCULATING VOLUME LOSS IN BALSAM FIR PULPWOOD FROM WOOD-BORING INSECTS. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 599, 2 pp., illus. (Processed.)
(Volume loss from species of *Monochamus* can be calculated for 100-inch balsam fir pulpsticks by counting the entrance holes to the larval tunnels and by knowing the stick diameter. A table is included to facilitate calculations.)

Wilson, Louis F. TN 610*
ATTRACTION OF WOOD-BORING INSECTS TO FRESHLY CUT PULPSTICKS. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 610, 2 pp., illus. (Processed.)
(Twelve species of wood-destroying insects, totaling 538 specimens, were collected over a 2-week period in August. The most abundant species was the white-spotted sawyer. Over one-half (229) of the total of this species (436) were

collected on the cutting day. This speedy attraction necessitates fast and efficient protection of summer-cut rough balsam fir pulpsticks.)

Forest Diseases

Anderson, Gerald W., and Schmiege, Donald C. SP 88*
THE FOREST INSECT AND DISEASE SITUATION, LAKE STATES, 1960. U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 88, 18 pp., illus. (Processed.)
(A cooperative report based on surveys conducted by Federal, State and private agencies in 1960.)

Van Arsdel, Eugene P. SP 92*
GROWING WHITE PINE IN THE LAKE STATES TO AVOID BLISTER RUST. U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 92, 11 pp., illus.
(Presents recommendations for reducing white pine blister rust losses by proper site selection and maintenance of favorable stand characteristics. The region is divided into four hazard zones based on climatic factors, and recommendations are presented for each zone.)

Van Arsdel, E. P.; Riker, A. J.; Kouba, T. F.; Suomi, V. E.; and Bryson, R. A. SP 87*
THE CLIMATIC DISTRIBUTION OF BLISTER RUST ON WHITE PINE IN WISCONSIN. U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 87, 34 pp., illus. (Processed.)
(In southern and lowland western Wisconsin, white pine blister rust was found most commonly in sheltered valleys, at the base of slopes, and in small forest openings. In northern Wisconsin it was general throughout the area, with least infection under tree canopies. Rust distribution seemed inversely correlated with average July temperatures.)

Forest Fire

Strothmann, R. O., and MacDonald, L. J. R 240*
WATER-BOMBING WITH THE DEHAVILAND BEAVER. U. S. Forest Serv., Fire Control Notes 22: 93-95, illus.
(Experimental drops were made from a Beaver equipped with a snorkel loading tube which filled the 125-gallon tank while the plane taxied across a lake. Dimensions of the effective pattern (0.4 gallon per 100 square feet and up) were much like those being obtained from other planes, except for a greater length. This, however, was offset by the much lower proportion of the area receiving amounts in excess of 1 gallon per 100 square feet. A larger, more efficient release hatch would probably overcome this difficulty.)

Forest Wildlife

Cooley, John H. TN 594*
SMALL DEER AND HARE EXCLOSURES CAN BE EFFECTIVE. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 594, 2 pp., illus. (Processed.)
(Tests of deer and hare exclosures 10 feet square and 4 feet high showed that small areas can be protected from deer browsing with relatively inexpensive fences. The essential feature of the exclosures tested was their small size which effectively discouraged entry by deer.)

Estimation of Timber Volume

Buckman, Robert E. R 246*
DEVELOPMENT AND USE OF THREE STAND VOLUME EQUATIONS FOR MINNESOTA. Jour. Forestry 59: 573-575, illus.
(Stand volume equations make a direct estimate of stand volume from the product of basal area and average height of the dominant stand. Equations for predicting stand volume were prepared for cubic feet, cordwood and board feet. The total cubic-foot and cordwood equations are composite in that they can be applied to several even-aged species in Minnesota; the board-foot equation should be used for red pine alone because it was developed from red pine data.)

Forest Economics

Beazley, Ronald I., and Lundgren, Allen L. R 232
FARM LUMBER CONSUMPTION AND USE, EAST-CENTRAL MINNESOTA, 1954. Univ. Minn. Agr. Expt. Sta. Sci. Jour. Series, Paper No. 4584, 58 pp., illus. (Processed.)
(Farms in the area studied used on the average 100 board feet of lumber for repair and 500 for new construction during the year. Most of the repair lumber and more than half of the new construction lumber came from local hardwoods, sold rough and mill-run. Volume of buildings was a poor indicator of lumber consumption while gross farm income was the best of those tested.)

Church, Thomas W., Jr., and Salminen, Wilho A. R 234
HOW CH[illegible]ES IN STAND DENSITY AFFECT SUG[illegible]LE STUMPAGE VALUES. Northeast. Logger 9(10); 14, 15, 52, illus.
(Old-growth stands of almost pure sugar maple were cut to various residual densities to show how stumpage values fluctuated. Relationships between residual density and value per MBF

and value per acre are given. Conclusions show that residual stumpage values per MBF can be increased through proper marking and cutting.)

Lundgren, Allen L., and Beazley, Ronald I. SP 93*
FARM LUMBER CONSUMPTION AND USE DATA: NEEDS AND METHODS OF ESTIMATING. U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 93, 20 pp., illus.
(This paper reports on the techniques for identifying and measuring lumber consumption and use on farms and the methods of sampling developed in a 1955 survey. It also presents recommendations for future surveys.)

Lundgren, Allen L. TN 611*
INVESTMENT OPPORTUNITIES IN REGENERATING BLACK SPRUCE ARE GREATLY AFFECTED BY SITE. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 611, 2 pp., illus. (Processed.)
(Site and land value greatly affect the margin for profitable investment in black spruce regeneration under the market and cost conditions outlined. On poor sites even the smallest investment in stand establishment is not profitable at discount rates above 2 percent.)

Morgan, James T. R 257
REVIEW OF "NEW LAWS FOR NEW FORESTS: WISCONSIN'S FOREST-FIRE, TAX, ZONING, AND COUNTY-FOREST LAWS IN OPERATION," BY ERLING D. SOLBERG, 611 PP., ILLUS., MADISON, WIS. Jour. Forestry 59: 686, 688.

Quinney, Dean N. R 247*
THE "FARM WOODLOT" REVISITED. Jour. Forestry 59: 601-602.
(A comment on the changing nature of small private forest ownership and some implications to forestry policy and programs.)

Quinney, Dean N. R 258
FOREST TO FARM—TO FOREST. Conserv. Volunteer 24(143): 20-21, illus.
(The decline in the number and acreage of active farms in 16 northern Minnesota counties has idled almost 1 million acres of land. The future use and ownership of such lands are uncertain, but some clues may be provided when data become available from the current third Minnesota forest survey.)

Quinney, Dean N. TN 600*
MORE FOREST LAND IN THE NORTHERN LAKE STATES? U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 600, 2 pp., illus. (Processed.)
(The number of farms and acreage in farm use in the northern Lake States have been steadily declining since 1945. On the basis of Census of Agriculture averages, apparently more than 2 million acres of crop and pasture land have gone out of production in the last 10 years alone. The future use of such lands is a provocative question.)

Schallau, Con H. TN 614*
DOWNWARD TREND OF WOODLAND GRAZING IN SOUTHERN MICHIGAN. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 614, 2 pp., illus. (Processed.)
(Less than one-fifth of southern Michigan's 2.6 million acres of forest land was pastured in 1959, representing a 43-percent reduction since 1945. This decrease in grazed woodlots was attributed primarily to a reduction in the number of dairy cows.)

Forest Resources and Timber Production Statistics

Blyth, James E. TN 608*
PRODUCTION OF MISCELLANEOUS TIMBER PRODUCTS—LAKE STATES, 1960. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 608, 2 pp. (Processed.)
(Shows production of miscellaneous timber products by species or species group in each of the three Lake States. Points out reasons for production changes.)

Horn, A. G. TN 606*
LAKE STATES PULPWOOD PRODUCTION UP 11 PERCENT IN 1960. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 606, 2 pp. (Processed.)
(Shows 1960 pulpwood production by species and destination of wood produced in each state. Imports from other states and Canada are shown separately for the Minnesota, Wisconsin, and Michigan mills.)

Horn, A. G. TN 609*
VENEER LOG PRODUCTION OF STANDARD GRADES UP SLIGHTLY, CONTAINER GRADES DOWN, LAKE STATES, 1960. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 609, 2 pp. (Processed.)
(Shows 1960 veneer log production by species and destination of wood produced in each state. Imports from other states and Canada are shown separately for the Minnesota, Wisconsin, and Michigan mills.)

tone, Robert N. TN 604*
CURRENT TIMBER GROWTH ESTIMATES FOR THE LAKE STATES. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 604, 2 pp. (Processed.)

(Summarizes growth estimates for Michigan, Minnesota, and Wisconsin as obtained in the second Forest Survey of these States. Estimates are by species for growing stock and sawtimber. Increased growth is pointed out by comparing current growth with that in the middle 1930's.)

tone, Robert N., and Bagley, Walter T. R 242*
THE FOREST RESOURCE OF NEBRASKA. U. S. Forest Serv., Rocky Mtn. Forest and Range Expt. Sta., Forest Survey Release 4, 45 pp., illus.

(Analyzes forest area, timber volume, timber growth, and timber use statistics for 1955 obtained from the first Statewide Forest Survey of Nebraska. Nebraska's 1,072,600 acres of forest are mainly in elm-ash-cottonwood and ponderosa pine types. Growth of growing stock and sawtimber is about three times the present timber cut although high-value species such as walnut are overcut. Poorly stocked stands of low-quality trees are commonplace, and as a result wood production is far below full potential in both quantity and quality.)

Stone, Robert N., and Thorne, Harry W. SP 90*
WISCONSIN'S FOREST RESOURCES. U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 90, 52 pp., illus.

(Wisconsin's forests as of 1956 were better stocked, volume was higher, growth was greater, and allowable cut was larger than that found by the first Survey in 1936. Considerable improvement had occurred in the overall size-class distribution, although serious gaps and deficiencies in important types remained, especially in the conifer types. Wisconsin's expanding pulp and paper industry used more wood than the sawmilling industry. Nearly 40 percent of the wood required was imported from out of State. More timber can be cut from certain hardwood species such as aspen, paper birch, ash and elm. If recent trends continue the forests will become better stocked and more productive than they are now.)

Forest Utilization and Marketing

U. S. Forest Service; Forest Products Laboratory; Southeastern Forest Experiment Station; and Lake States Forest Experiment Station. R 241*
CHARCOAL PRODUCTION, MARKETING, AND USE. Forest Prod. Lab. Rpt. 2213, 137 pp., illus.

(Presents data on small charcoal kiln design, operation techniques, and costs of production obtained in research and experimental work conducted by the U. S. Forest Service at several locations in the United States. It was found that cinder-concrete block kilns of 2- to 10-cord capacity, when operated at temperatures of 850° F. to 950° F., can be simple in design, low in cost, and produce good quality and good yields of charcoal.)

Forest Recreation

Bultena, Gordon; Lucas, Robert; and Hathaway, William SP 89*
RECREATION IN THE UPPER GREAT LAKES AREA; A SUMMARY OF SOCIAL RESEARCH. *In* Outdoor Recreation in the Upper Great Lakes Area; Proceedings of a Seminar in Research Needs, May 11-13, 1961. U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 89: 17-38, illus. (Processed.)

(Reviews 147 studies of recreational land use, economic impact of outdoor recreation, economic demand and value, the characteristics and attitudes of recreationists, projections of recreational use, and policy formation. Trends in research are also considered. The number of publications is increasing, but there still seems to be considerable fragmentation and a lack of interdependence between studies.)

U. S. Forest Service, Lake States Forest Experiment Station. SP 89*
OUTDOOR RECREATION IN THE UPPER GREAT LAKES AREA: PROCEEDINGS OF A SEMINAR ON RESEARCH NEEDS, MAY 11-13, 1961. U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 89, 104 pp., illus. (Processed.)

(Sixteen papers on recreation research presented at a conference held at the University of Wisconsin; also summaries of discussion groups. Authors are sociologists, geographers, foresters, and others from Michigan, Wisconsin, Minnesota and Ontario.)